POWER PLANT ENGINEERING

Established Over 28 Years

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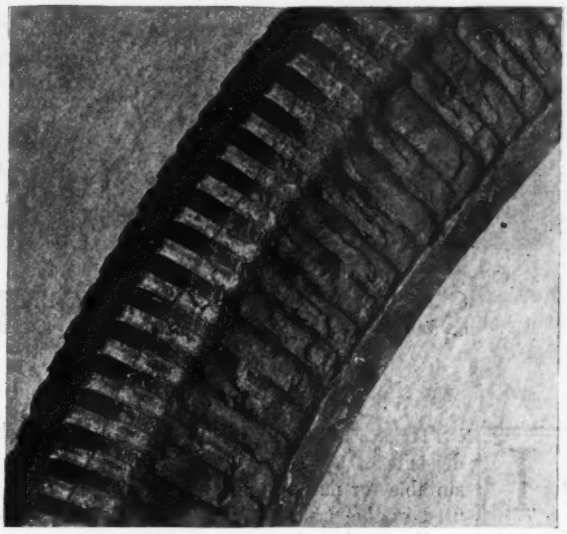
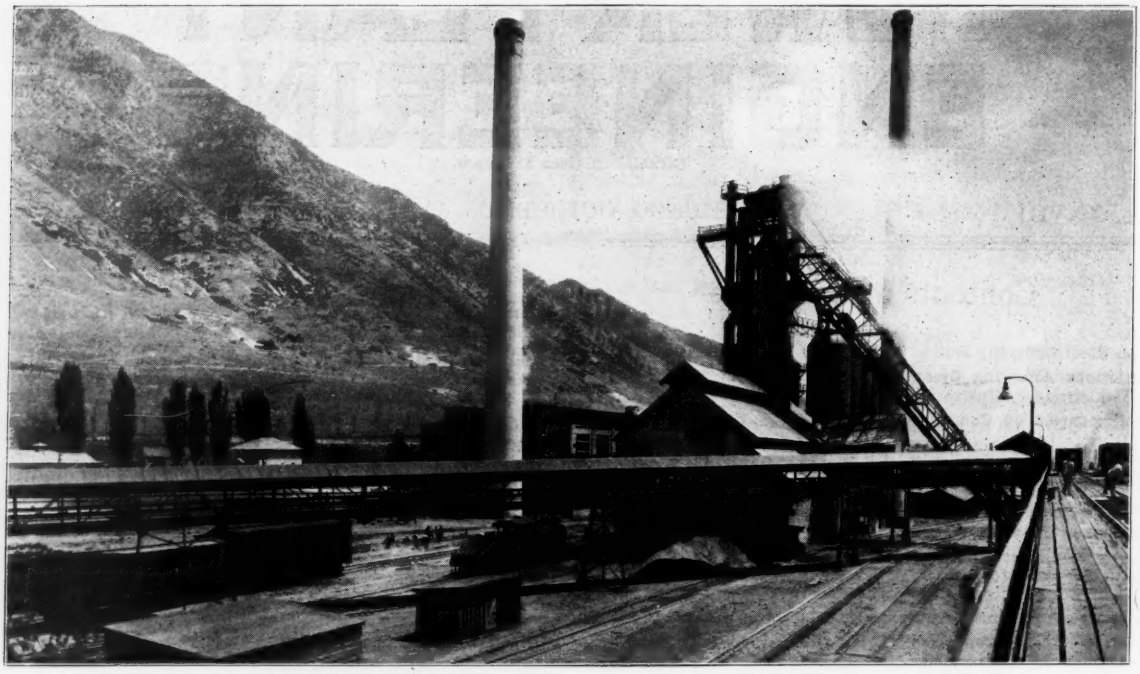


Detour—Take Bypass

CAN WE wonder that turbines fall off in capacity and efficiency when such a condition as shown above is occasionally found at the time a turbine is opened up for inspection? Scale accumulation on the blades, while one of the most common, is only one of several causes of lowered efficiency which occurs during the operation of a turbine. Some of these always exist but are likely to grow worse with continued use, others are the direct result of operation and increase in their detrimental effects until replacements are necessary, still others may be entirely removed at times of cleaning only to reappear as operation continues. All of these causes are given consideration in the article by Mr. Dahlstrand appearing in this issue.

ACCORDING to our standards of comfort the inside of a condenser tube would hardly be considered a desirable place to live and we should not expect the conditions prevailing favorable to the support of life. But nature is adaptable and, in spite of the adverse conditions, the inside of a condenser tube forms the abode of countless millions of tiny organisms which taken together form the tenacious non-conducting lining so detrimental to efficient operation. To prevent the growth of these organisms, some bright individual in England conceived the happy idea of sterilizing the circulating water with chlorine. This has proved highly effective and many plants are using the process. Details in this issue.



Steel Company Builds New Power Plant

ELECTRIC POWER, COMPRESSED AIR AND STEAM FURNISHED TO BLAST FURNACE AND COKE OVEN PLANTS LOCATED NEAR IRON ORE AND COAL FIELDS

IN THE STATE of Utah are great commercial deposits of a good grade of iron ore and coal suitable for making gas and coke which can be used in the production of iron and steel. Accordingly, there has recently been put in operation at Provo the new blast furnace and coke plant of the Columbia Steel Corp.

This plant is advantageously located in that the haul for both ore and coal is about 100 mi. from the mines to the blast furnace. The altitude of Provo is about 4800 ft. above sea-level. The coal mines, which are southeast of Provo, are at a higher altitude than the plant. The same relation of relative altitudes also holds true with respect to the ore mines and the plant, so that all heavily loaded raw material trains from the mines to the plant have a predominating down-grade haul and the empty trains going back to the mines work against a predominating up-grade.

At present practically all of the pig iron produced at this plant is shipped to the Pacific Coast. In the shipment of pig iron the prevailing grade is again in favor of the heavily loaded cars and thus it appears that Provo is ideally located with respect to raw material and the shipment of the finished product to the market.

As might well have been expected the question of water supply was one which required careful consideration. The supply of water for the power plant was but part of the problem because comparatively large quantities of water are required in connection with the processes of reducing the ore to cast pig iron.

In the immediate vicinity of the plant is an irrigation canal which affords an ample supply of water for condensing and mill purposes but which is unsuitable for boiler use without first treating it. It is used therefore only for the former purposes. Although there is an ample supply of this water, the engineers have made economical use of it.

This water is taken from the canal and discharged by gravity into a supply basin from which it is taken by the pumps which deliver it to the condensers. These pumps are known as the primary pumps. At the present time two pumps have been installed and provision has been made for a future turbine driven unit. The water ends for these pumps were furnished by the De Laval Steam Turbine Co. They are 14-in. single-stage, double-suction, centrifugal pumps. One pump is driven by a Westinghouse turbine which is rated at 55 hp., 1000 r.p.m., 200 lb. pressure and 125 deg. F. superheat. The other pump is driven by a 50-hp. General Electric Co. motor. The characteristics of these pumps are such that they will start the condensers without the air ejectors having been first turned on. The motor-driven pump will normally be in operation.

CONDENSING WATER USED FOR MILL PURPOSES

At the base of each condenser is to be found the usual well, the height of water in which is held constant by a weir. The waste water from this well flows over the weir into a second well from which the secondary pumps draw water for mill service. Three secondary pumps have been installed and provision has been made for the installation of two additional steam-driven units. The units which are installed at present are one motor-driven unit which is rated as follows: Motor—General Electric Co., 150 hp., 1800 r.p.m., 3 phase, 60 cycle, 2300 v.; pump—10-in. single stage, double suction, centrifugal. The steam-

driven pumps are the same as the above and the turbines are rated as follows: De Laval Steam Turbine Co., 150 hp., 2500 r.p.m., throttle pressure 200 lb. and superheat 125 deg. F.

These pumps are equipped with constant pressure governors, the motor-driven pump operating at constant speed and the steam-driven units take the fluctuations. The exhaust from the steam units is discharged to the heaters.

Boiler Water Taken from Wells and Springs

Several flowing wells had been drilled on the property, the water from which had been found suitable for boiler purposes. The temperature of the well water is as would be expected about 60 deg. F. This water is supplemented with that from some natural springs, located about ¾ mi. from the plant. The spring water is brought to the plant through a wooden flume and is mixed with the well water.

Method of handling the water through the plant is as follows: the well and spring waters flow into a mixing basin located outside of the power plant building. Located within the building are two 10 by 14½ by 12 in. Worthington direct-acting pumps which draw water from this well and force it through the blower jackets and raise two-thirds of it to the open-type feed-water heaters which were furnished by the Worthington Pump & Machinery Corp. Each heater is rated at 100,000 lb. of water per hour and will carry the load on the plant. Exhaust steam from these cooling water pumps goes to the feed-water heaters.

This water is well adapted to cooling the blowers because it will not form a scale within the temperature range through which it is used. In passing through the blower jackets the temperature of the water is raised to about 85 deg. F.

Approximately 65 per cent of this cooling water is required for boiler feed, therefore about that percentage is drawn off after passing through the jackets and is forced directly to the feed water heaters. The remainder or 35 per cent of the jacket water, is returned to the well where the spring and well waters are mixed. In this way about one-third of the water is recirculated. The heat thus reclaimed from the blower jackets amounts to approximately 166 B.t.u. per gallon of water circulated.

Boiler-feed pumps draw water under a positive head from the heaters and deliver it to the boilers through Copes feed-water regulators, the boiler pressure being 225 lb. per sq. in. gage. The boiler-feed pumps consist of two 4-in., horizontal, four-stage, double-suction, impellor, split-case pumps, each rated at 400 g.p.m. One of these pumps is of ample capacity to carry the entire boiler load.

Two Westinghouse steam turbines have been installed to drive these feed pumps. These turbines are rated at 120 hp. each at 2520 r.p.m. To supplement the boiler-feed pumps and also to furnish emergency water to the blast furnaces there has been installed a third unit which was furnished by the Worthington Pump & Machine Corp. It is of the horizontal, direct-acting type. Its size is 20 by 12 by 15 in. and it is rated at 570 g.p.m. This pump is piped so that it can take raw water either from the wells and spring and feed it to the boilers direct, or from the heaters and deliver it to the boilers, or it may take mill supply water from the condenser wells and deliver it to the blast furnace.

Equipment Located in the Turbine Room

Two turbo-generators are placed in the turbine room with their steam ends toward the boiler room. These units

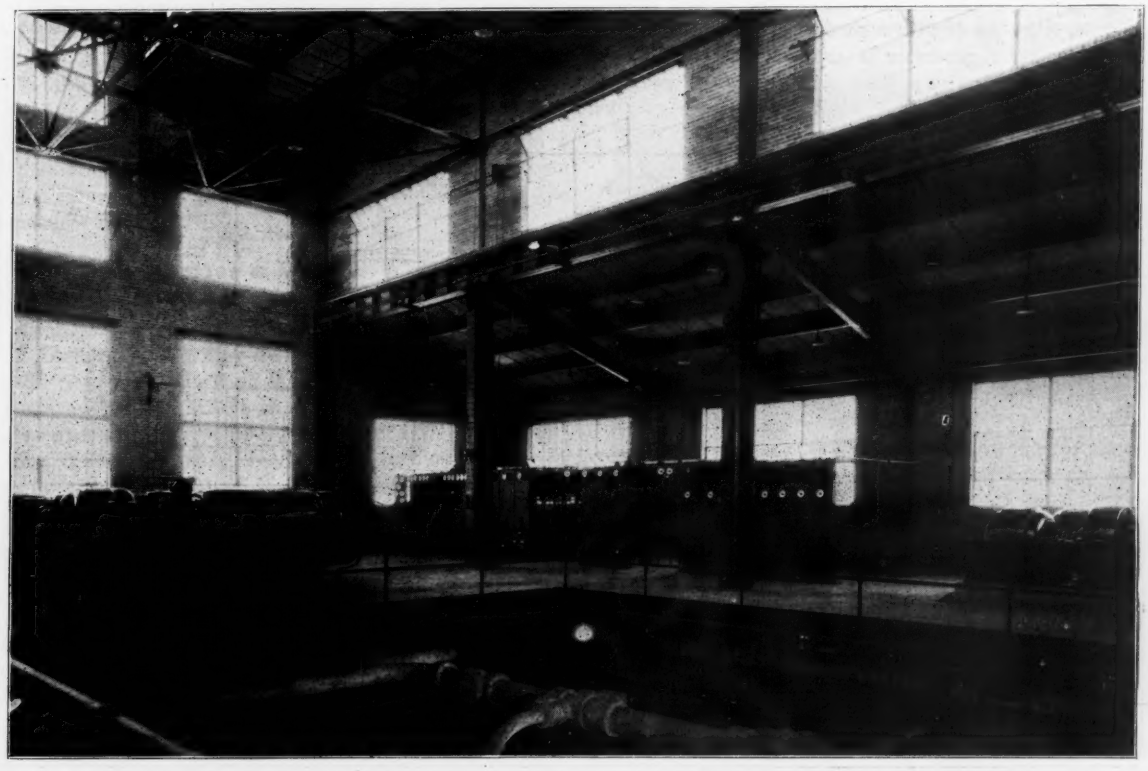


FIG. 1. GENERAL VIEW LOOKING TOWARDS THE TURBO GENERATORS AND THE LEAN-TO WHICH HOUSES THE ELECTRICAL BAY

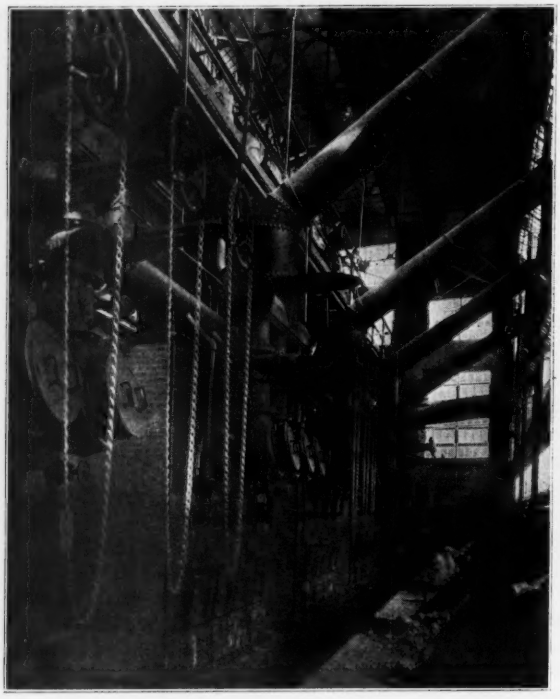


FIG. 2. BOILERS ARE EQUIPPED TO BURN COKE-OVEN GAS, BLAST-FURNACE GAS OR COAL

were furnished by the General Electric Co. and each is rated at 1500 kw. 3 phase, 60 cycles and 2300 v., the power factor being stated as 80 per cent.

Cooling water for the turbine bearings is connected to the cooling water line which leads to the blower jackets. The water after passing through the bearings is carried to the sewer. Each generator is provided with a separate air duct, equipped with a Reed air filter, which conducts cooling air from outside the building to the generators.

Another interesting feature of this turbine installation is the fact that both turbines are connected to one barometric-type condenser which is of ample capacity to hold a vacuum within ¾ in. of absolute when one turbine is carrying full load. This condenser was furnished by the Ingersoll-Rand Co., and it is rated to condense 40,000 lb. of steam per hour. With both turbines on this condenser the vacuum would be somewhat less than when serving a single unit.

As previously stated Provo is located at an altitude of 4800 ft. above sea level so the absolute vacuum which can be obtained under ideal conditions would be about 24.7 in. of mercury and the boiling temperature corresponding to this pressure would be about 202 deg. F. The vapor temperature corresponding to this pressure is about 138 deg. F. These figures are quite in contrast with those employed in the calculations for turbine and condenser work at sea level wherein an absolute vacuum of 29.9 in. of mercury may be obtained and where the boiling point is 212 deg. F. and the temperature of the vapor at absolute vacuum would be about 32 deg. F.

One question which naturally arises is as to the resultant steam economy of a turbine which operates at high altitudes where absolute vacuums of 24 or 25 in. are all that can be obtained. The answer to this is that the turbine economy is for the most part based upon the total steam pressure drop between the throttle and the condenser. A vacuum of 24 in. means that the drop in pressure has been cut down about 2 lb., however, this can be made up by increasing the incoming steam pressure a like amount. The resultant turbine economy would then be practically the same as though the turbine operated under the same drop in pressure but at a lower vacuum.

Low pressure steam connection is made to each turbine by attaching a 36 in. expansion joint directly to the turbine casing. To this is attached a special 36 by 36 by 14 in. ell which is provided with a drilled base so that the fitting is supported from the floor. This fitting is of particular interest in that the sweep at the turn is greatly

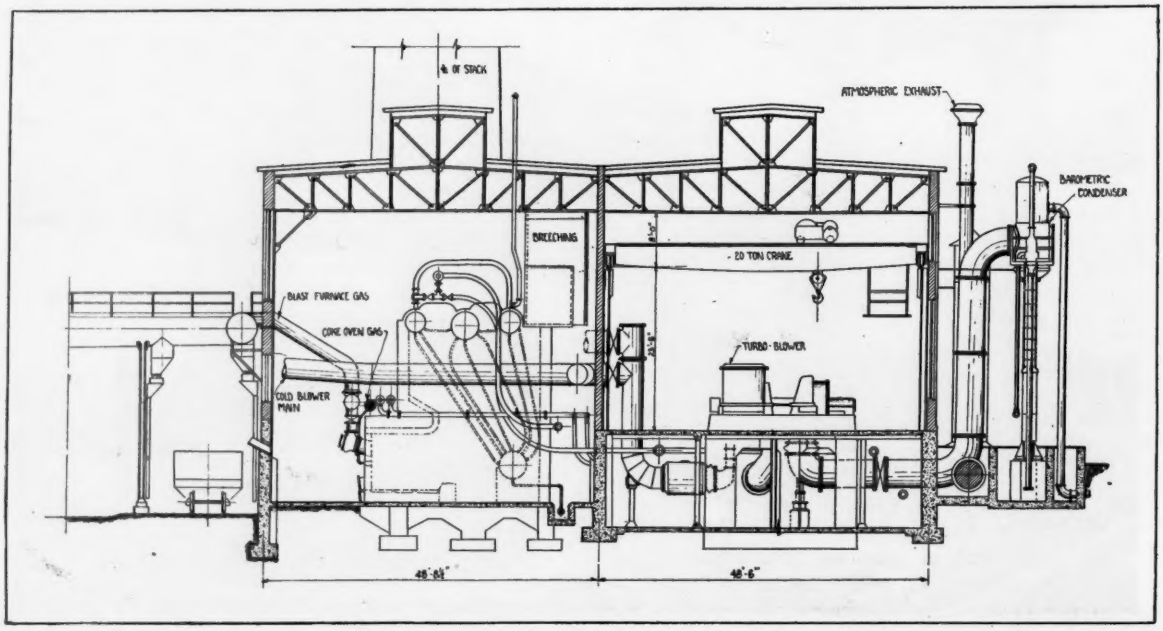


FIG. 3. CROSS-SECTIONAL ELEVATION THROUGH BOILER ROOM AND TURBO-BLOWER END OF TURBINE ROOM

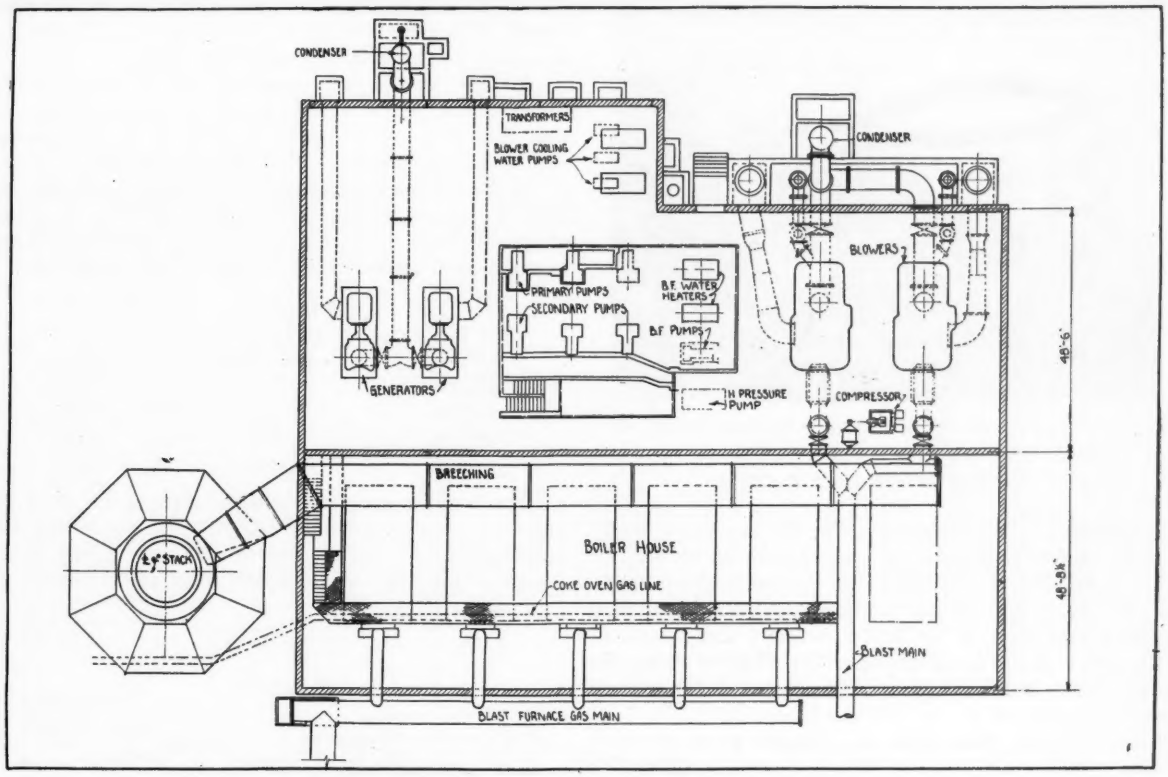


FIG. 4. GENERAL PLAN OF THE COMPLETE POWER PLANT

enlarged thus cutting down the resistance to steam flow. To the 14-in. connection is attached a Davis exhaust relief valve. The outgoing steam from this valve is piped horizontally through the building wall and then vertically up to a 14-in. Hoppes exhaust head located above the roof. A 1-in. drain is located in this line near the relief valve.

Connected to each special ell is a 36-in. gate valve. The steam from the two turbines comes together in a double branch flanged elbow. From this elbow the steam is led through a 36 in. by ⅜ in. steel riveted pipe to the condenser head.

Pipe Drainage is Well Worked Out

Drainage connections are made to each special elbow and the double branch elbow. These drains come together and discharge into a 3 by 6-ft. tank which is designed for 30 lb. pressure. This tank is provided with a gage glass, an air relief valve, a 1½-in. spring loaded Crane safety valve and a float operated mechanism for an electrical alarm arranged to ring a bell on the turbine floor when the tank has become filled to a predetermined level.

This tank is not connected up to a vacuum trap but it is required that the operator drain it. This is accomplished at present by opening the drain at the bottom and the air cock. This method imposes an extra load on the condenser air ejectors because the air which is left in the empty tank must be expelled. It is contemplated that a steam connection will be made to the tank so that it will not be necessary to admit air when draining it, but flood it with steam which will condense and thus relieve the extra work which is now imposed upon the ejectors. The drainage from this tank is run to the sewer.

Thoroughness of the details of pipe drainage and the care which has been exercised to cut down the friction losses between the turbine and the condenser are fine examples of practice which would be advisable on similar

FIG. 5. VIEW SHOWING TURBO-BLOWERS AND HIGH AND LOW PRESSURE STEAM PIPING TO AUXILIARIES

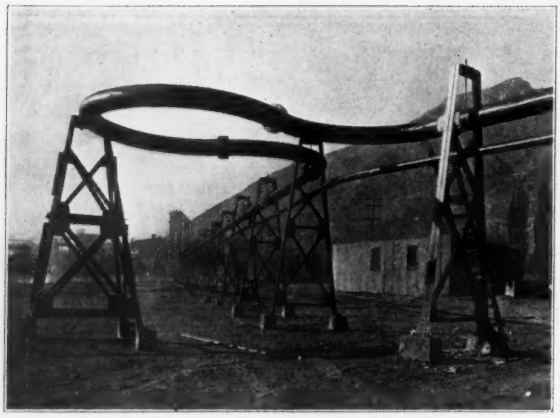


FIG. 6. EXCELLENT EXAMPLE OF OUTDOOR STEAM PIPE CONSTRUCTION SHOWING EXPANSION BEND, SUPPORTS AND ANCHORAGE

installations. In ordinary practice the condenser would be but a few feet from the turbine exhaust nozzle. In this installation the corresponding distance is about 100 ft.

Contrasting this barometric condenser installation with a similar one at sea level it is found that because of the lower atmospheric pressure the distance from the water level in the hot well to the center of the exhaust steam connection to the condenser head is 32 ft. 6 in. Since this is a 36-in. pipe, the distance from the water level to the lower edge of the pipe would be but 31 ft. This of course is good practice for an altitude of 4800 ft. because the most perfect vacuum possible could not pull water over into the exhaust line.

Pumps installed for a condenser of this kind must be able to pump against the head of water as indicated by the difference between the water level maintained by the vacuum in the tail pipe and the point of discharge of the water into the head. To this must be added the friction and velocity heads in the water pipe. This explains why as far as pump capacity and power required are concerned, it is good practice to take advantage of lowering the condenser head at high altitudes.

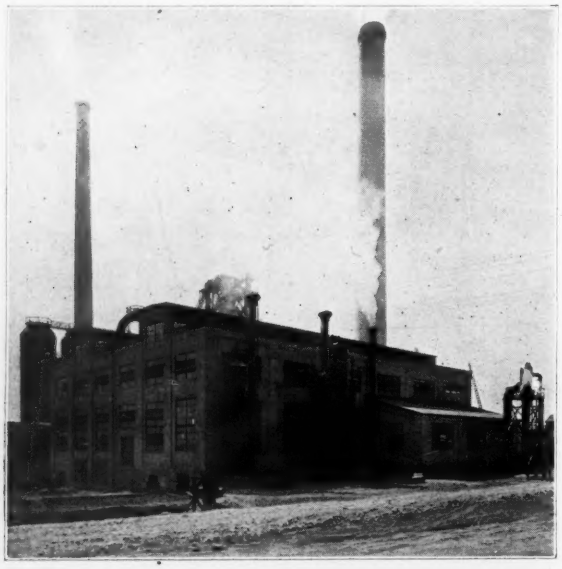


FIG. 7. GENERAL VIEW OF THE PLANT SHOWING THE BAROMETRIC TYPE OF CONDENSERS AND THE INTAKES FOR THE TURBO-BLOWERS

Air ejectors for the condensers are of the two-stage inter-cooled type and operate at 100 lb. steam pressure so that they will not be handicapped as to their capacity should the boiler pressure drop far below normal.

In the turbine room are also to be found two Ingersoll-Rand Co. steam turbine-driven, centrifugal blower units, of special design because of the altitude, which supply air to the blast furnaces. Each blower is rated as follows:

Cu. ft. air per min.	Discharge pressure lb. per sq. in.	R.p.m.
50,000	17	2950
42,000	17	2800
30,000	28	3100
42,000	25	3100

The turbines are supplied with steam at 200 lb. pressure and 100 deg. F. superheat. One Ingersoll-Rand Co. barometric-type condenser serves the two blower units. This condenser is rated at 40,000 lb. of steam per hr.

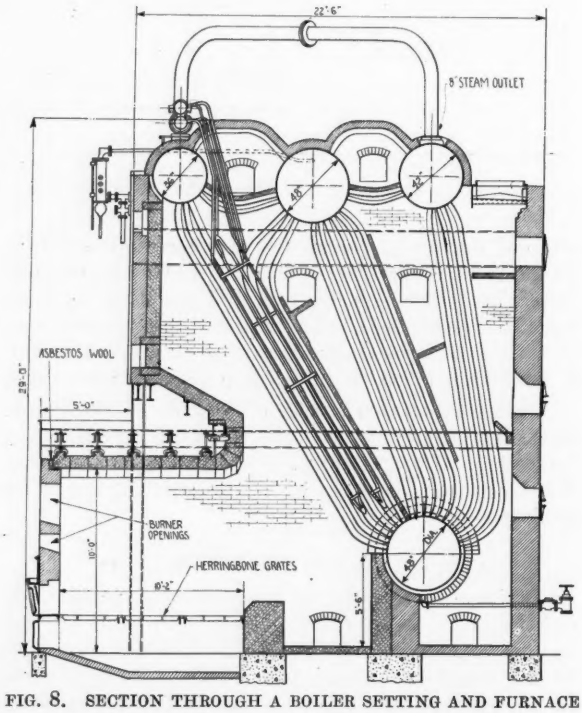


FIG. 8. SECTION THROUGH A BOILER SETTING AND FURNACE SHOWING LOCATION OF GAS BURNER OPENINGS IN FRONT FURNACE WALL

One air compressor has been installed. This is of the duplex type made by Ingersoll-Rand Co. and is rated at 357 cu. ft. free air per min. with a final discharge at 100 lb. pressure. This unit is driven through a short belt by a 50-hp. General Electric Co. motor. The action of the compressor and motor is automatic throughout. When the air reaches a given pressure the automatic electrical control comes into play so that the motor is stopped and the unloading valves opened. When the pressure drops to a certain point the motor automatically starts and the unloading valves do not close until the motor has reached

Data on Power Plant Equipment Used by the Columbia Steel Corporation

General

Location of plant	Provo, Utah
Character of service—Compressed air power and light for blast furnace and coke plant.	
Elevation	4800 ft. above sea level
General dimensions—	
Boiler house	144 ft. by 48 ft. 8½ in.
Turbine room	144 ft. by 48 ft. 6 in.
Electrical bay	72 ft. by 22 ft.

Boilers, Superheaters and Accessories

Maker of boilers	Heine Boiler Co.
Type	"V," water tube
Number installed	5
Heating surface, each	6170 sq. ft.
Grate area	110 sq. ft.
Furnace volume	1700 cu. ft.
Boiler pressure	225 lb. gage
Ratio heating surface to grate area	56 to 1
Ratio furnace volume to heating surface	0.276
Maker of superheater	The Superheater Co.
Superheat	125 deg. F.
Maker of furnace arch	American Arch Co.
Feed-water regulator	Northern Equipment Co.
Non-return valves	Schutte & Koerting Co.
Piping	Pittsburgh Piping & Equipment Co.

Chimney

Designed by	The Heine Chimney Co.
Diameter at top	12 ft.
Height	240 ft.
Supported on	Concrete block

Electrical Machinery

Turbo-alternators—	
Manufacturer	General Electric Co.
Number installed	2
Capacity, each	1500 kw.
Power factor	80 per cent
Speed	3600 r.p.m.
Characteristics	3 phase, 60 cycles, 2300 v.
Steam pressure	200 lb. gage
Superheat	125 deg. F.
Exciter	Direct connected
Motor-generator sets—	
Manufacturer	General Electric Co.
Number installed	2
Capacity, each	300 kw.
A.C. motor	3 phase, 60 cycles, 2300 v.
D.C. generator	230 to 250 v.
Electric switchboard—	
Manufacturer	Westinghouse E. & M. Co.
Panels—9 A.C., 2300 v.; 3 A.C., 400 v.; 8 D.C., 230 v.; 1 battery charging.	
Transformers	Pittsburgh Transformer Co.
Lightning arrestors	General Electric Co.
Condensers for turbo-generator—	
Manufacturer	Ingersoll-Rand Co.
Number installed	1
Type	Barometric
Capacity	40,000 lb. per hr.
Air pump	2-stage ejector with interstage cooling

Turbo Blowers

Manufacturer	Ingersoll-Rand Co.
Number installed	2
Steam pressure	200 lb. gage
Superheat	100 deg. F.
Speed	3100 r.p.m.
Pressure of air	25 lb. gage
Air capacity	4200 cu. ft. per min.
Condenser-maker	Ingersoll-Rand Co.
Number installed	1
Type	Barometric
Capacity	40,000 lb. per hr.
Air pump	2-stage ejector with intercooling

Air Compressor

Manufacturer	Ingersoll-Rand Co.
Type	Duplex
Free air capacity	357 cu. ft. per min.
Final air pressure	100 lb. gage
Driven by	General Electric Co. motor
Rating of motor	50 hp., 2300 v.

Feed-Water Heaters

Manufacturer	Worthington Pump & Mach. Corp.
Number installed	2
Type	Horizontal, open
Capacity, each	100,000 lb. per hr.

Boiler-Feed Pumps

Pumps—Manufacturer	Worthington Pump & Mach. Corp.
Number installed	2
Size and type	4 in., 4-stage centrifugal
Capacity, each	400 gal. per min.
Governors	Fisher differential
Drive-turbine	Westinghouse E. & M. Co.
Horsepower	120
Speed	2520 r.p.m.

Primary Pumps

Manufacturer	De Laval Steam Turbine Co.
Number installed	2
Type and size	14 in. single stage, double suction, centrifugal
Steam turbine drive	Westinghouse E. & M. Co.
Horsepower	55
Speed	1000 r.p.m.
Steam pressure	200 lb. gage
Superheat	125 deg. F.
Motor drive	General Electric Co.
Rating of motor	50 hp., 2300 v., 900 r.p.m.

Secondary Pumps

Manufacturer	De Laval Steam Turbine Co.
Number installed	3
Type and size	10 in. single stage, double suction, centrifugal
Steam turbine drive	Westinghouse E. & M. Co.
Number	2
Horsepower	150
Speed	2500 r.p.m.
Steam pressure	200 lb. gage
Superheat	125 deg. F.
Motor drive	General Electric Co.
Number	1
Horsepower	150
Speed	1800 r.p.m.
Voltage	2300
Governors	Fisher constant pressure

Miscellaneous Pumps

High pressure pump	Worthington Pump & Mach. Corp.
Number installed	1
Size	20 x 12 x 15 in.
Capacity	570 gal. per min.
Type	Horizontal duplex, outside packed
Blower cooling pumps	Worthington Pump & Mach. Corp.
Number installed	2
Size	10 x 10¼ x 12 in.
Capacity	500 gal. per min. each
Type	Horizontal-duplex

Miscellaneous

Structural steel	American Bridge Co.
Steel sash	Truscon Steel Co.
Crane	Cleveland Crane & Eng. Co.
Air filters	Reed Air Filter Co., Inc.
Oil filters	Wayne Tank & Pump Co.

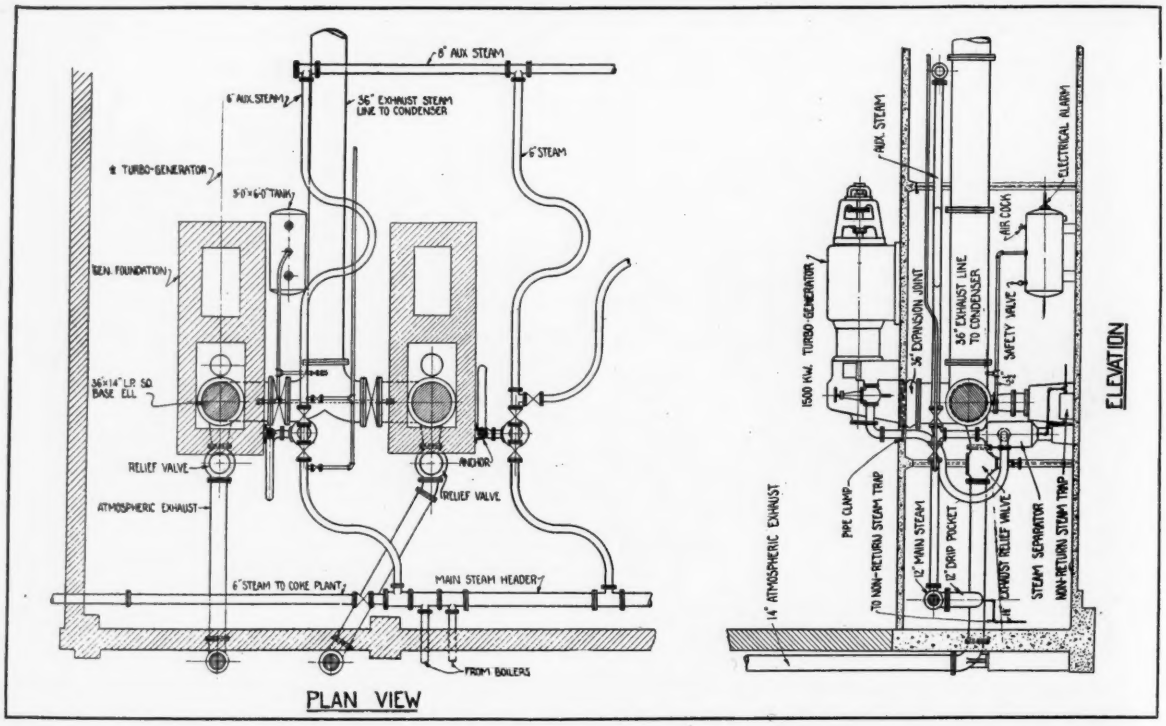


FIG. 9. HIGH AND LOW PRESSURE PIPING FOR THE TURBO-GENERATORS. TURBO-BLOWER ARRANGEMENT IS SIMILAR

its normal speed. The altitude at which this unit works determined the selection of the duplex type.

Located also in the turbine room are two motor-generator sets of 300 kw. capacity each. These were furnished by the General Electric Co. The motors are operated at 2300 v. and the d.c. generators furnish current at 230 to 250 v. These sets are securely fastened to a section of the floor which is specially designed to avoid deflection and ballasted with concrete so that the frames are absolutely rigid and the machine operation vibrationless.

Switchboard equipment is located just opposite the two alternating-current generators. The oil switches are manually controlled through link motions and are so located back of the board that all parts are readily accessible. In the basement, beneath the board, is a room devoted to electrical apparatus, in which are located the rheostats, one lighting transformer, three 2300 to 440-v. power transformers and pump controls. This location of the transformers does away with the necessity of an outdoor substation.

All a.c. motors throughout the power plant are operated on 2300 v. current. Both 2300 and 440 v. alternating current are used for motor operation at the coke ovens.

Details Were Worked with Great Completeness

This plant is located a long distance from where materials can be quickly obtained. Therefore the engineers found it desirable to detail all parts of the work so that every necessary item would be on the job at the right time. This detailing helped further because much of the work had to be carried on by comparatively unskilled labor. An interesting example of this care in detailing is evident in the electrical layout which included a diagram showing just where the electrical-cable reels should be placed in the yard and just how much cable was to be taken from each reel in the various directions in which the conduit ran. Further details were given of each manhole showing the location of each cable splice to be made at that point.

In the boiler room are located five "V" type Heine boilers, each of which is set singly. Data on these boilers are as follows: square feet of heating surface each, 6170; grate area, 110 sq. ft.; boiler pressure 225 lb. gage; furnace volume, 1700 cu. ft. The superheaters, which furnish steam at 125 deg. F. superheat, were furnished by The Superheater Co. These settings are not particularly high and are along the general lines of the Dutch-oven type, the arches having been furnished by the American Arch Co. These furnaces are interesting in that they are designed for use with three different fuels; namely, blast furnace gas, coke oven gas and coal.

Blast furnace gas results from the process of reducing iron ore to pig iron. A part of the gas is used for heating the stoves and the surplus is ordinarily used under the boilers. This gas ranges in heating value from 90 to 100 B.t.u. per cu. ft.

Blast furnace operation requires the use of large quantities of coke and it is general practice to build a coke plant near the blast furnaces. One of the by-products from the coke plant is a rich fuel gas which averages about 550 B.t.u. per cu. ft. The boiler furnaces are equipped with burners so that this gas may be used in place of or to supplement the blast furnace gas. Coke oven gas has a high commercial value therefore this gas will be used under the boilers, as a supplementary fuel, only when there is no commercial demand for it.

To forestall the possibility of periods when no gas would be available for firing the boilers each setting is equipped with a flat grate upon which coal may be hand fired. The coal used will average about 12,500 B.t.u. per

lb. as fired. Normally when gas is used as a fuel no coal is fired and the grates are covered over with ash to protect them from the heat of the furnace.

Coal is handled by a locomotive crane from standard railroad cars into hoppers hung on the outside of the boiler room wall. Chutes discharge the coal from these hoppers to the boiler room floor

One chimney, 12 ft. in diameter at the top and 240 ft. high, serves all the boilers. It was built of reinforced concrete by The Heine Chimney Co.

Building construction is of steel with brick filled walls. The roof is of poured gypsum which is then covered over with a 4-ply composition roofing material. Gypsum was used in this case for a good reason other than that it is proof against drippage from condensation. It is an extremely light weight material and therefore could be transported the long distance out to Provo at a substantial saving in freight as compared with other roofing materials.

One of the foremost considerations in the design of this plant was that of low first cost without putting in either inferior equipment or sacrificing economy and reliability. An example of this viewpoint in design is that of the installation of one barometric-type condenser to serve two units. This selection saved not only in the cost of condensing equipment but also in the cost of excavating and construction below the turbine room floor.

Design and construction of this blast furnace and power plant was supervised by Freyn, Brassert & Co., Chicago, Ill. Appreciation is herewith expressed to the above engineers, for information supplied for the preparation of this description.

Conditions Affecting Steam Turbine Economy

Outline of Conditions Which Interfere With Maintenance and High Economy. Suggestions for Obtaining Best Results. By J. Y. Dahlstrand

NO OTHER PRIME mover has the inherent ability to maintain for long periods of time its original efficiency in the same degree as has a steam turbine. It comes, however, within the capability of the designer as well as the operator, to make this condition better or worse, through proper and careful design and through intelligent operation.

Practically all builders of steam turbines allow a certain tolerance in connection with turbine tests to cover a given period of time after its installation. This tolerance is supposed to cover material wear and tear on a machine and the resulting falling off in efficiency. It ordinarily amounts to from 1 to 2 per cent per year for the first 3 or 4 yr. It is questionable whether in actual practice the efficiency of the machine falls off any at all if it is properly designed and maintained. Tests have been conducted on turbines after 6 yr. of continual operation and the same results were obtained as at the time of the original test.

It is the intent of this article: First, to enumerate those causes which most frequently interfere with continued maintenance of high economy in a steam turbine; second, to outline means at the disposal of the designer, to combat those causes and the effects; third, to give advice to owners and operators with respect to operation in order that they may get the best possible results.

Internal Leakage Is One Cause of Loss

Among those causes for falling off in economy which the designer has to some degree, ability to control and forestall through careful design, is internal leakage. It is a dangerous cause since it generally remains undetected for long periods of time. Steam leakage in the interior of a turbine is always present to some degree with all reaction turbines and all impulse turbines having more than one stage. Since in reaction turbines expansion of the steam takes place in both stationary and revolving blade rows, close clearances must be maintained at the ends of both stationary and rotary blades.

Corrosion of the casing and the rotating drum at the clearance points over the blade tops is one of the causes interfering with maintenance of the original status of this leakage over long periods of time. This corrosion is most likely to take place in case of intermittent operation and impure feed water. There is also erosive action of the steam which is not so likely to take place on account of low velocities, unless the steam contains a great deal of moisture. In certain reaction turbines the design has been so modified that the clearance is not radial but axial. This may have many important advantages in minimizing leakage since practically all turbines of drum type operate above their critical speeds and whirling of the rotors when starting and stopping unquestionably has the tendency to increase the radial clearance. With these axial clearance turbines the clearance becomes a factor dependent upon the thrust bearings.

Internal leakage of multi-stage, impulse turbines takes place through the shaft plans between the stages but due to the small areas compared with nozzle and blade areas, this leakage is normally of no great consequence.

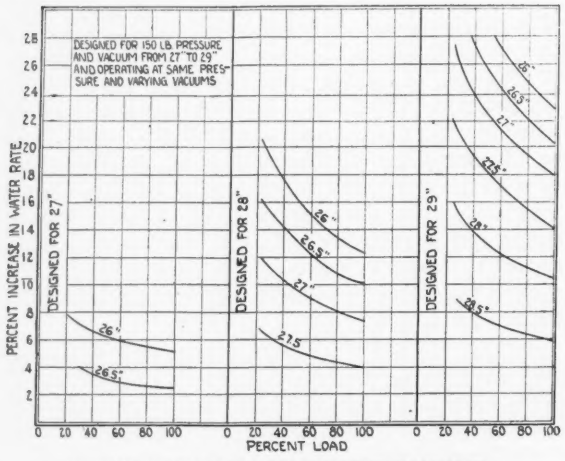
Packings for the diaphragms are either of the fixed labyrinth type or the floating type. The former has to be resorted to in case of large shaft diameters and is successful provided the shaft is "stiff"; in other words, if it has no critical speeds within the operating range. If the shaft is "flexible," then a floating packing is much to be preferred. Causes which tend to increase leakage are about the same as enumerated under reaction turbines—namely, corrosive action and with labyrinth glands also erosive action.

Sometimes steam leaks occur on multi-stage turbines on the horizontal joint between the diaphragms due to improper workmanship or careless packing of the joint at that point. As with all types of leaks, if this condition once exists it will steadily get worse if not remedied. A leak at that point will sometimes develop an end thrust on the turbine, due to the fact that steam can not escape fast enough at the circumference of the disk. A condition still worse is the steam leakage from the steam end of the steam head into the first stage. On steam turbines having steam admission in both upper and lower halves with a hole in the flange connecting the two steam spaces, leakage is likely to take place because of the lack of bolting and due to the fact that pressure tends to open the joint. In certain turbines, the high pressure steam space is separated from the vacuum space by means of an internal gland.

Classed with internal leakage of the turbine could rightfully come leakage through overload or bypass valves, supposedly closed, actually partly open. The effect of such conditions on the steam performance of the turbine can not be neglected. In actual test a slightly open overload valve will materially influence the final results. High pressure valves with mixed pressure turbines which fail to close tight even though adequate low pressure steam is available, might also be classed here and represent conditions which are detrimental to good performance.

As has already been stated, the designer has it within his power to help conditions of internal leakage in practically all types of machines. It is the writer's opinion that more cooperation between the operator and the designer would be highly beneficial. Tests of machines after several years of operation, without reconditioning before the test, would also be beneficial.

Several things are unquestioned: First—Non-corrosive materials are always advisable where commercial conditions will permit them. Second—Ample surfaces for steam



EFFECT OF VACUUM ON TURBINE ECONOMY

packing joints and ample bolting to assure tight joints should be provided. Third—Design should be such as to preclude all possibility of joints opening up, or packing blowing out at points to which the operator has no ready access and points where leakage might occur without being discovered by the operator.

One cause of loss which comes to some degree within the province of the designer may be classed steam spillage, or in other words, mis-direction of the steam jets so as not to have proper effect on the revolving blade rows. This condition is unusual with axial flow machines unless caused through outright bad machine work on the turbine. It might also be caused by excessive wear on bearings.

As a form of steam spillage may also be classed the case where the blading is designed for a different ratio of wheel and steam velocities than it is actually used for in operation. This causes the steam to impinge first upon the back side of the blading instead of the front. This condition is likely to take place on high economy machines operated at a low load factor in which case the steam velocity will be cut down to a much lower point than the turbine is normally designed for.

Corrosive action is always present to some degree on all turbine nozzle and blading made of cast iron and steel. Experiments on "stainless steels" conducted by some companies abroad and by one manufacturer in this country, seem to have given satisfactory results. A non-corrosive alloy for both nozzles and blading would unquestionably prove most satisfactory from this standpoint.

Nozzles Are Subject to Corrosion and Erosion

Erosive action, all other things being equal, is also more likely to take place where corrosion has first gotten in its work. Corrosion and erosion pit the surfaces of nozzles and blading and this increases the losses. They also eat away and dull the edges of the blades causing steam shock, thus reducing the power and increasing the steam consumption of the turbine. Corrosion is intensified by intermittent operation due to the admission of air alternately with steam, the oxygen in the air attacking the blade surfaces. It is also increased with the extent of moisture in steam and acids in the feed water. With superheated steam and continual operation, corrosion is less common. Erosion increases as the ratio between the steam velocity and the blade velocity increases. It is hence worse in single-stage machines with low speeds and high pressure drops.

Blade materials which have most successfully withstood erosive action include cupro nickel, monel metal and stainless steel. Drop forged unfinished nickel steel buckets have also given fair results particularly where too much moisture was not present in the steam.

As the axial clearance on a Curtis or Rateau turbine is materially increased over a normal of $\frac{1}{16}$ in. there generally takes place a falling off in power and steam performance. Particularly is this true with expanding nozzles in the machines of the former type. It is generally considered good practice to under-expand somewhat the steam in the nozzles, the final expansion taking place within the first revolving blade row. This condition will be disturbed in increasing the clearance. In Parson turbines the axial clearance, due to the low velocity, does not materially affect the power of the machine. In all types of turbines it is advisable, from a standpoint of economy and safety, that the operator know exactly the clearance in his machines. Designers ought to provide on all turbines an indicator some place on the exterior of the machine which will show the operator at all times the minimum clearance.

Turbines, even though properly designed as far as nozzles and blading are concerned, are likely to suffer from restricted or misdirected flow. Without going into any great detail on this matter, it might be stated as a general rule applying to turbine design that the flow of steam in the passages between the nozzles should be as frictionless as possible and should be directed either in exactly a correct direction, or, if this can not be done with certainty, fluid passages should be large so as to reduce the velocity losses at such points to a minimum.

Foreign Substances May Clog Blades

Restriction of flow is often caused by a clogging of blades and nozzles by foreign substances. This trouble usually occurs when a turbine is being fed by one or more boilers which are giving about their maximum capacity.

In some steel mill districts the deposit consists principally of a muddy material which is bound together by chemicals existing in the water. At the velocity at which steam enters the blades any material carried in the steam

will be impelled against the blades with such velocity that it will form a compact deposit.

Steam that is exceptionally wet, when made from water containing scale-forming material, such as magnesia and other salts, will invariably deposit a scale-like substance over the turbine blades.

There are various means of combating the clogging of blades from the above-mentioned causes. One which is frequently used, particularly for non-condensing turbines, is the placing of a lubricator in the turbine steam line. The oil vapor in the steam lubricates the blade surfaces and prevents the substances from becoming attached. Even for condensing turbines this method is frequently used although it would appear not to be entirely advisable in installation where surface condensers are used, on account of oil deposits which would be found on the tubes.

Undoubtedly the most effective means of preventing this trouble is that of installing a large receiver in the steam line. The steam velocity will be decreased greatly while passing through this receiver and the foreign substances will be deposited on the walls. In addition to the receiver there should be installed near the turbine throttle a steam separator.

EFFECT OF BACK PRESSURE ON TURBINE ECONOMY

Steam Pressure	Add for each pound back pressure
200 lb.	1½ per cent
175 lb.	1¾ per cent
150 lb.	2 per cent
125 lb.	2½ per cent
100 lb.	3 per cent
75 lb.	3½ per cent
60 lb.	4 per cent

Foremost among operating conditions affecting operating economy in the steam turbine unit comes falling off in vacuum in the exhaust chamber. This results in the most serious loss in economy and is a condition often found in small plants. The effect of low vacuum on steam consumption is illustrated in the curves given herewith. As will be noted, the percentage loss is greatly increased as the output decreases due to the fact that throttling takes place at a pressure below the full load ring pressure and the number of heat units represented by the difference adiabatically, become of a greatly increased percentage to the total energy available for use in a turbine. Low vacuum may be due to many causes such as clogged condenser tubes, leaky or inadequate air pumps and not infrequently leaky turbine glands or exhaust pipes.

Whatever the cause of low vacuum it is generally money well spent to find the cause of it. As may be seen in the above charts, even one-tenth of an inch better vacuum might figure out to be a paying proposition over a period of time.

Closely related to low vacuum comes high back pressure with non-condensing turbines. The steam turbine suffers more severely from increased back pressure than the steam engine due to increased rotation losses. The effect of back pressure on a steam turbine is shown in the table given herewith. The figures given will not hold true for all outputs and speeds but may be taken as fair average values.

Moisture in steam affects the steam consumption of a turbine to a higher degree than that of an engine. For the first 3 per cent of moisture it is customary to add 6 per cent to the steam consumption or 2 per cent for each per cent of moisture.

To operate multi-stage turbines as well as single stage turbines without nozzle control at partial load is nearly always connected with loss in steam performance.

First Aid Instruction Is Valuable

TO KNOW what to do in an emergency is the important thing, writes Dr. Harry W. Gentles, in a recent publication of the National Safety Council. The man who can put his thumb on an artery spurting blood and hold it there until someone else can summon a physician will often save a life.

Almost equally important is the knowledge of what not to do. The good Samaritan who runs to the assistance of a man who has fallen from a scaffold and hoists him to his feet converts a simple fracture into a compound. The man who paints an infected wound with iodine a second or third time and the policeman who has to be knocked down before artificial respiration can be applied to a gas victim are other examples of dangerous ignorance.

In the well-organized plant there are always first aid kits for emergency treatments. Where possible it is better to have the injury dressed by the plant physician or nurse but, often, men are obliged to work at some distance from the hospital or dispensary and promptness in treating an injury is vital. First aid kits are useless, however, unless the men have been trained to use them properly. Undoubtedly, much of the objection to first aid by laymen is due to the malpractice of untrained amateurs. The well meaning but ignorant first aider may cause a burn which is worse than the original abrasion through the injudicious use of iodine or he may contaminate the dressing by careless handling. The trained man, however, knows what to do and he does it while his fellow workers are debating what should be done in suggesting all manner of crude remedies.

Benefits of first aid instruction received in company classes will not be confined to the plant. At home, on the street and on vacations, emergencies may raise at any time when the training of the first aider may save a life. Proper first aid training by teaching persons to think clearly and act promptly will help to prevent accidents in addition to minimizing the severity of those which do occur.

WHEN A CONDENSER of the jet type is used, an automatic device should be installed which will break the vacuum when the water in the condenser reaches a dangerous height. If no provision of this kind is made and the air pump is of the attached type any slowing down of the engine is likely to cause the condenser to become flooded; in which case water would flow back into the engine cylinder and the engine might be wrecked or badly damaged. Overspeed devices, when used on condensing engines, should be arranged to break the vacuum as well as to shut off the steam.

Fundamentals of Combustion Control*

RATE OF FUEL FEED, AMOUNT OF FORCED AND INDUCED DRAFT ARE THE ESSENTIAL CONTROLS FOR THE COMBUSTION PROCESS. BY E. G. BAILEY†

COMBUSTION control has been approached from so many different angles that it may be best to consider it basically and see just what factors we are dealing with and how best to correlate them to obtain the desired results.

The problem is basically the same no matter whether we burn coal on a stoker or in pulverized form, or whether we burn oil, gas or a mixture of fuels. We must supply fuel in proportion to the demand for steam and at the same time furnish the necessary air for the desired combustion efficiency.

To meet the varying demands for steam the rate of fuel and air supply must be changed from time to time.

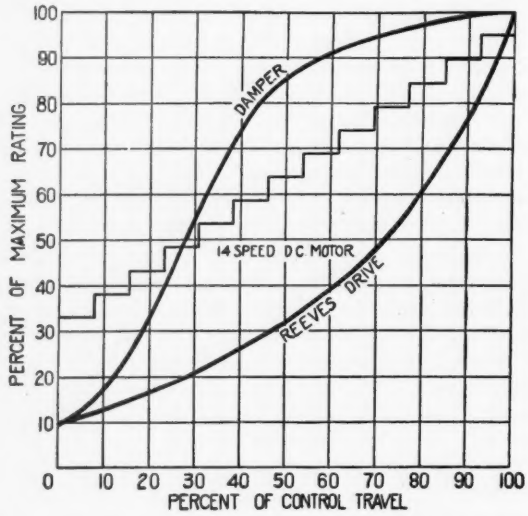


FIG. 1. CHARACTERISTICS OF CONTROL EQUIPMENT FOR A STOKER-FIRED BOILER SHOW WHY FUEL AND AIR PROPORTIONING IS NOT CORRECT AT ALL LOADS

This calls for variable speed control of the fuel if fed in pulverized form or on mechanical stokers, also variable speed of the fans for forced and induced draft, or the use of valves or dampers for pressure control of gas, oil and air supply. It may seem like a simple problem to calibrate each of these controls and determine just what result or what capacity of each will be obtained and then determine the relationship of the position of one to the other, but the same quantities are not always delivered for the same position of a valve or damper, or the same speed of a stoker and fan, and quite often the control system must be called upon to readjust the relationship between these different factors, not because the load has changed, but because the quantity delivered has not remained constant even though the position of the controlling device has remained unchanged.

It is, therefore, necessary to find a control device that will regulate each of these movable elements to bring about the correct final results in balancing the fuel supply in proportion to the demand for steam and also obtain the proper relation between fuel and air, regardless of whether the change is due to total load of the station, the shifting of load from one boiler or group of boilers to another or the change in the supply of fuel and air due to numerous operating conditions.

*Paper read before the Association of Iron and Steel Electrical Engineers.

†President, Bailey Meter Co.

DAMPER REGULATOR WAS FIRST FORM OF COMBUSTION CONTROL

Earlier forms of combustion control consisted of a damper regulator operated by steam pressure which supplied more or less air in proportion to the demand for steam, leaving it for the fireman to keep the fuel bed in the desired condition to utilize this air whenever and however it entered the furnace. As mechanical stokers replaced the hand fire and better oil and gas burners became available, the next step in regulation was to change the supply of fuel as well as the air.

Some systems changed the fuel and air simultaneously in presumably the right relation while others would increase the air supply by opening the damper and then the furnace draft would, in turn, increase the supply of fuel. The former system of direct connection between the fuel and air may be considered as a parallel system of control, while the other is a series or tandem system, but in neither case is there any definite assurance that the correct relation between fuel and air will always be maintained for best combustion efficiency, or that the fuel bed will be kept in the desired condition. This is really the crux of the problem and it is necessary to have a thorough understanding of exactly what the control characteristics are for the different ways of supplying fuel and air to boiler furnaces, and the limitations of accuracy to repeat the same quantities for different positions of control.

CHARACTERISTICS OF CONTROL EQUIPMENT

Figure 1 shows the characteristics of the control equipment for a stoker-fired boiler with chimney draft carrying the gases away and the air supplied by forced draft. The forced draft fan is operated by a d.c. motor with 3 to 1 speed control having 14 points. The rate of supply of air from the fan motor alone would increase by steps as indicated. If the draft in the furnace was controlled by an uptake damper of the usual type it would have a characteristic similar to that shown, provided the damper was tight so that it could be closed to an air supply of not over 10 per cent of the maximum. The rate of fuel supply is shown as being controlled by a variable speed transmission of the cone pulley type between a constant speed motor and the stoker with a 10 to 1 speed range.

Assuming that all this equipment was designed so that at the maximum damper opening, maximum motor speed and the maximum stoker speed these would all be properly proportioned for best combustion efficiency, it is obvious that at no other rating would they be together unless the travel of the control was different in each case. In no case would the forced draft fan be slowed down sufficiently for as low a rating as could be obtained from the damper and the variable speed drive. This would necessitate a further control of a damper between the forced draft fan and the stoker.

If the boiler was to operate at 74 per cent of its maximum rating the forced draft fan motor would be on the ninth step, the induced draft damper should be 40 per cent open, which on a 90 deg. damper would be about 36 deg. open, and the variable speed drive control should be in a position of 89 per cent of its maximum travel. As none of the control lines run parallel from this point, either above or below, it is very difficult for these to be connected together on any parallel system of automatic control.

Object of Control Is to Obtain Definite Results

There is, in my opinion, only one correct way to regulate anything and that is to move the various controls the necessary amount in order to obtain certain definite results. Take for illustration the simple case of a water tank from which water is drawn for a variety of industrial purposes and it is desired to maintain a reasonably constant level of water in the tank. If this were to be accomplished on the parallel system of control it may be illustrated as having a meter measuring the discharge from the tank and another meter measuring the supply of water replacing it. It is obvious that if by either hand control or automatic control the two meters are always kept to read exactly the same and both meters are exactly alike, the water level will be maintained. This, however, requires an accuracy of a millionth of one per cent, because any error or difference between the two would mean an accumulative result and the tank would either run empty or overflow.

Another similar illustration of parallel control would be to connect the discharge valve with an inlet valve of a tank so that when one opened the other would open and expect the amount drawn out would be exactly replaced and the water level maintained. It is obvious that this could not be accomplished, for no matter how accurately the valves were calibrated and checked against each other, the pressures will not remain near enough constant to assure equal flow through the two valves.

We will all readily agree that the only sensible way of replacing the water as it is drawn out is to use a float control valve which will maintain a constant level by controlling the water supply as determined by the water level itself, which is the one final result of accumulated difference between the inflow and outflow.

The control of one factor as illustrated above is comparatively simple but where more than one factor is involved we often try to regulate two or more factors from one source of control. The same basic reasoning, however, holds, that we must select a final result which will act as a reliable guide for each individual factor to be controlled. This is analogous to solving for unknown quantities in algebra. We know we must have an equation for each unknown, also these equations must be true equations to represent the proper relationship between the various unknowns.

Three Essential Controls for Combustion Process

To illustrate this, Fig. 2 represents diagrammatically a steam boiler plant involving three controls for the combustion process; namely, fuel, forced draft and induced draft. To operate this plant satisfactorily these three basic controls must be guided by certain definite results. The first of these is steam pressure. Steam pressure is an indication of balanced relation between the inflow and outflow of B.t.u. from the boiler proper. When the steam pressure holds constant it indicates an exact balance. When the steam pressure is dropping it shows that the steam is carrying heat out of the boiler faster than the fuel is replenishing it; therefore the call for a higher rate of combustion.

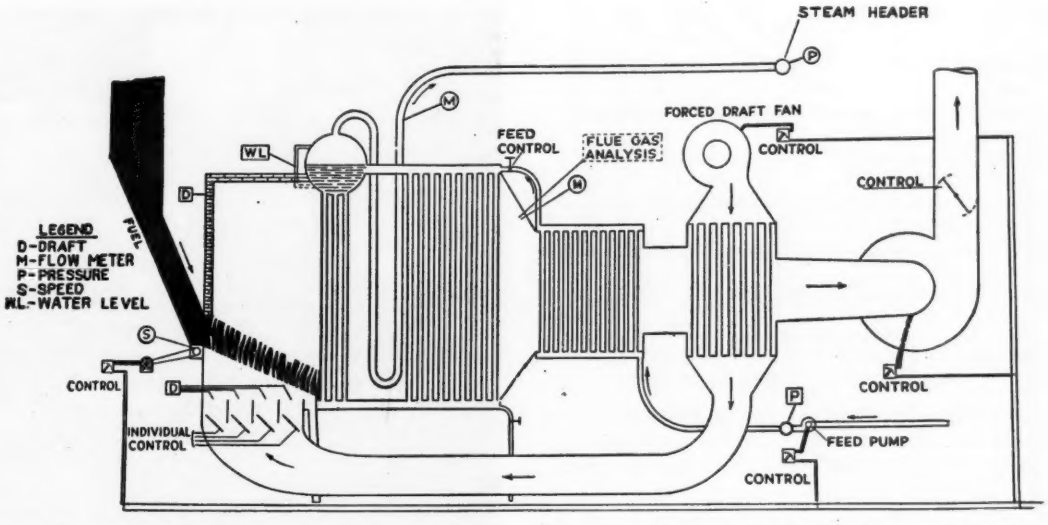


FIG. 2. THREE POINTS OF AUTOMATIC COMBUSTION CONTROL ARE INDICATED HERE—FUEL FEED, FORCED DRAFT AND INDUCED DRAFT

To supply this heat from coal or fuel in any form requires air, or in the case of a fuel bed if the coal is already on the grate, then the supply of air will be sufficient, but burning away of the coal calls for a replenishment of the fuel in order that the desired fuel bed conditions be maintained. A drop in steam pressure therefore calls for simultaneous increase of both the fuel and air supply. In the case of stokers with fuel beds the need for this exact synchronism of events is not so essential as it is in the case of pulverized fuel, gas and oil.

The second problem of control is the relationship between the fuel and air in order to maintain combustion efficiency. We know that the relationship between fan speed or damper position and air supply is not at all accurate. We also know that the relation between stoker speed, feeder speed, position of oil or gas valves does not hold a definite relation to the fuel supply. If these relationships did exist then every valve, every rheostat and every damper would be a meter and all we would need to do would be to record or note its position and we would know the quantity of fluid or material passing through it. We must, therefore, search for a definite final result equivalent to the water level in the tank to guide us in

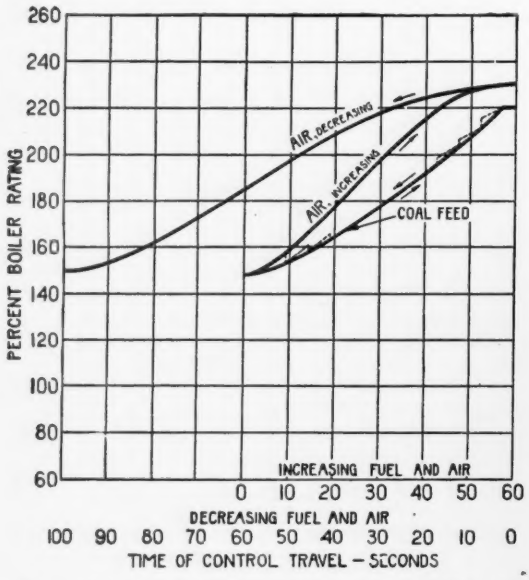


FIG. 3. AUTOMATIC CONTROL BY STEAM PRESSURE ALONE CAUSES AIR SUPPLY TO INCREASE FASTER AND DECREASE SLOWER THAN FUEL SUPPLY WITH CHANGES IN LOAD

controlling the available speed or quantity changing devices to obtain the desired relationship.

Combustion Efficiency Determined by Percentage of Excess Air

Experience has shown that the only feasible guide for combustion efficiency is to determine the percentage of excess air. The desired percentage of excess air for best combustion efficiency is that which will maintain the total losses due to excess air and unburned fuel at a minimum. Or, if the brick work is the essential factor, as it often is, one should maintain the lowest percentage of excess air and yet not encounter too great an expense in maintaining the brick work and furnace lining.

The steam-flow-air-flow relation is a positive, instantaneous and correct indication of the percentage of excess air and is well adapted as a guide for either hand or automatic control. The rate of steam generated is in reality the reading of a calorimeter showing the rate at which B.t.u. are developed in a furnace. The flow of air as indicated by the differential pressure across the boiler with proper precautions, is a measure of the rate of air supplied to develop the B.t.u. Fortunately the B.t.u. per pound of air used in combustion is substantially constant for all commercial fuels and the relation between steam flow and air flow is, in reality, a relation between the B.t.u. supplied to the furnace in the fuel and the air supplied to the furnace for burning it with the desired percentage of excess air.

The third factor for controlling this combustion process is found in the furnace draft pressure as being a balance between the induced draft and the forced draft. In other words, this is equivalent to the water level in a tank where it is desired to take the gases out from the furnace as fast as the air producing combustion is entering through the forced draft ducts. Balanced draft control is well known and has been used to great advantage for a number of years, but everyone realizes its limitations as it controls only one thing, viz., the relation between outgoing gases and incoming air, and has completely ignored the all-essential factor of controlling the fuel supply to maintain steam pressure and also to vary the air supply in proportion to the fuel for best combustion efficiency.

For best results, the system of control which must be carried out is the same whether it is done by hand or

FIG. 4. BOARD SHOWING METERING EQUIPMENT APPLIED TO A PULVERIZED COAL FIRED BOILER

automatic means. This involves simultaneous changing of the rate of fuel and air supply to meet the demand for steam, and then readjusting the induced draft fan to obtain the desired percentage of excess air and also readjusting the forced draft fan to maintain the proper furnace draft. If the induced and forced draft have both been changed simultaneous with the fuel they need only be slightly readjusted, using the excess air and the furnace draft as guides in obtaining the correct final adjustment. A good fireman, with hand control, does identically this very thing and no system of automatic control will be successful unless it carries out the same procedure as a good man would do with good controllable equipment available for accomplishing any desired result called for as he observes the combustion and operating conditions.

There are some problems of control which come up in case of fuels burned in suspension which call for cer-

tain requirements to obtain best efficiency, as well as certain safety factors which are not required in stokers.

Take for instance a pulverized coal fired boiler with natural draft and damper control for air supply and a Reeves Drive controlling the speed of feeders for fuel supply. As seen from the curves of Fig. 1, it is impossible by any parallel travel to maintain the proper relationship between air and coal, as the air supply follows the relation as governed by the damper, while the coal feed follows a portion of the reciprocal curve of the Reeves Drive. There is furthermore an uncertainty as to just how much coal will be obtained for any given change in feeder speed and also how much the air may be increased for any given change in feeder speed and also how much the air may be increased for any given damper opening. The coal factor varies in most feeders with the amount of coal in the bin, the percentage of moisture, etc., while the air for any given damper position will depend upon how many other boilers are on the stack, weather conditions, etc. It is therefore obvious that in order to make a safe increase in boiler rating the air should be supplied faster than the fuel in order that any deviations from the desired combustion efficiency will tend towards an excess of air which is always safe from smoke or other difficulties, and later the air should be readjusted by hand or automatic means to suit the amount of fuel actually being fed to the furnace, as guided by excess air.

Rate of Change in Control Adjustment

When decreasing the rate of steam output it is best to bring the air down more slowly than the fuel so as to tend again toward an excess of air, and later readjust the air down to the exact amount of fuel as required for best combustion efficiency. A good fireman would naturally make these changes in inverse order, that is, when increasing the rating he would increase his air supply and then bring the fuel up. In decreasing the rating he would decrease the fuel supply and then bring the air down. To accomplish this with automatic control requires a different speed of the control of either the fuel or the air, or both, according to the direction in which it is going. Figure 3 indicates what is to be accomplished by automatic control. If the control is made by steam pressure alone, the air would go up faster than the fuel, leaving it in excess. The air would come down slower than the fuel, again leaving it in excess, or working toward a high excess of air at all times. It should not be allowed to remain in this condition, however, and continuous readjustment toward the excess air would cause the actual increase and decrease of the air to follow closely the fuel feed, but tending toward the upper side as shown by the small steps just above the coal feed curve.

It should be borne in mind that the increases in coal and air do not follow lines as shown in either Figs. 1 or 3, but they are bands of considerable width depending upon the variations of air and fuel supply for any given position of the damper or feeder speed changing device. It is not at all uncommon to find a variation of 30 or more per cent in the rate of pulverized coal discharge for a given feeder speed and under many conditions a variation in air flow of 20 or more per cent takes place with the same position of the damper, in the case of natural draft, and are less changed in the case of fans.

Another point of particular importance in the control of boiler equipment as shown in Fig. 2 is the feed water. It is obviously impossible to have the feed water controlled in proportion to the steam output without the net final result of water level in the boiler as the final controlling guide. In other words, the water level is the final guide as to whether the amount of water leaving the boiler in steam, leakage or blowoff has been replaced from the feed line. The control of the feed valves may have to be changed from time to time even though the rate of steaming has not changed; such changes in feed valves being called for because of change in feed line pressure, or change in boiler pressure.

There is the same need for controlling all the combustion factors, such as fuel and air supply, from final results, the same as have been and always will control the feed water from the water level, thereby at one stroke correcting for all factors such as change of feed water pressure, steam pressure, leakage, blow-downs, as well as the rating. Any system of combustion control must be equally flexible in meeting the individual requirements which must be maintained.

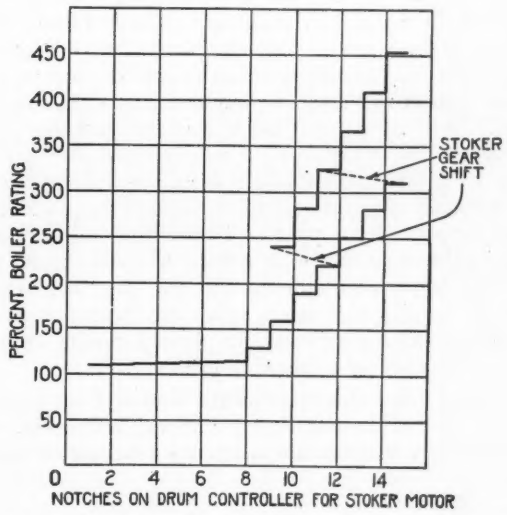


FIG. 5. SPEED CHANGES OBTAINED BY AN IMPROPERLY DESIGNED 14-POINT CONTROLLER

Control Equipment for Pulverized Coal Fired Boiler

Figure 4 shows a metering equipment applied to a large pulverized coal fired boiler, part of which is used in the automatic system and the remainder is indicating the operating conditions. The system of control there illustrated is operated by pilot motor mechanism of special construction and handles several boilers from one master control panel which can be either automatic or push button in case other than the standard pressure is desired, or if for any reason the operator wishes to meet any emergency. From this central panel the control, either automatic or push button, increases the fuel and air supply to each boiler simultaneously. The air supply is controlled by induced draft fan motors, together with dampers for bringing the rating down to less than that corresponding to the lowest fan speed. The fuel is controlled by rheostats on the d.c. motors operating each individual feeder. The air to the hollow wall ducts is con-

trolled by spring balanced dampers so as to maintain the desired distribution of air at the different levels.

At the individual boiler panel as shown in Fig. 4, each of the feeder motors can be started or stopped and it is necessary to stop some of these motors for the lower ratings, as all feeders at the lower speeds will supply enough coal for about 120 per cent of boiler rating.

It is also possible to stop and start the two induced draft fans from this panel board, although they are normally stopped and started by the automatic control in conjunction with the damper position and the boiler rating required.

When bringing a boiler on the line or doing any unusual thing with it, the operator has push button control completely independent from the automatic. For instance, the central drum switch in No. 1 position enables the operator to supply more air by increasing the fan speed or opening the dampers according to their position, covering both fans and dampers if they are both connected through from the individual drum switches to the central drum, or they can be controlled individually if desired. From the No. 2 position of the central drum switch the push buttons will then increase or decrease the supply of fuel. In No. 3 position the boiler is on base load conditions and the drum switches will increase both the fuel and air for each individual boiler alone and the air will be automatically and continuously readjusted to suit the fuel supply. No. 4 position is the same except that it carries through to the central panel where the steam pressure or the push button control at that point takes care of the capacity of this boiler, while the steam-flow-air-flow readjustment accomplishes the desired results in maintaining the proper combustion efficiency.

Many difficulties of automatic control have been laid at the door of the manufacturer of such equipment, while in reality it was the uncontrollable relationship between the factors that could not be properly obtained or maintained.

Handicap of Improper Control Design

To a certain extent, the firemen on hand control have been greatly handicapped due to the lack of proper relationship between the controller travel and the results obtained therefrom. For instance, Fig. 5 shows speed obtained from a d.c. motor on a stoker where a 14-point controller gave very little speed change in the first seven points, then beyond that each step was in reality too great for good results.

In one plant a 60-point rheostat was installed, yet only about 1/3 of the speed range of the pulverized coal feeders could be used within the limit of the air supply, which was the maximum obtainable from the stacks themselves. In another case the lowest feeder speed gave over 200 per cent of boiler rating and in similar conditions stokers are often found where the lowest speed obtainable would operate the boilers very nicely at 250 per cent rating, yet the fireman is called upon to operate the boilers on an average rating of 150 per cent, which can be accomplished in such cases only by stopping and starting the stokers.

The operator can obtain much better results in many cases if he is given good controllable motors and dampers over the desired range of operation, and furthermore if such control is brought to the meter board or at a convenient place in the boiler front where he can observe operating conditions while changing the controls and maintain them as desired instead of having it scattered all over the boiler room, or not within ready reach at all.

Automatic control is not justified in all existing boiler plants, but there seems to be no excuse why all control necessary for the fireman to operate should not be brought to a common point with the proper metering equipment to indicate his operating conditions and thereby enable him to accomplish the best results without useless physical effort.

Powdered Coal for Small Boiler Plants---III*

Comparative Advantages and Desirable Characteristics of the Unit Pulverizer Are Discussed. By T. W. Atterbury

WHERE A unit pulverizer is used the burner is simply an extension of the fan discharge pipe to the combustion chamber and may be made of steel plate or it may have a cast-iron nozzle where it enters the combustion chamber. The mixture of air and coal from the pulverizer being of fairly uniform density where a short run of piping is used, no mixing device is necessary for firing boilers. When the pulverized coal is drawn from a bin, however, some mixing of the coal and air is necessary. A burner and mixer for this purpose is shown in the accompanying illustration.

Burners may enter the combustion chamber through the roof or through the front wall, depending on the type of boiler and the combustion chamber design. Illustrations of both types have been shown in the preceding articles. The stack draft should be of only sufficient intensity to create a partial vacuum in the combustion chamber in order to have a slight induction action on the coal and air entering the chamber. Without this action the openings for air admission will be smoky and the burners will tend to clog up.

Uniform feed and uniform density of the coal and air mixture result in steady furnace conditions and simplify the firing operations and, therefore, are greatly to be desired.

With vertical burners where the combustion chamber is deep and the path of the gases is long, a velocity of 6000 ft. per min. is frequently used for the coal and air mixture passing through the burners. On horizontal fired boilers this velocity is lower, usually around 2000 to 3000 ft. per min. The velocity of the secondary air which is induced around the burners or through the openings in the combustion chamber wall is relatively low from 1200 to 2000 ft. per min., being caused principally by the stack draft of 0.1 to 0.25 in. of water. In addition, however, an injector effect is caused by the higher velocity air and coal passing through the burner, which draws in some of the secondary air around the burners.

To fire a pulverized coal boiler in such a way as to form a light, friable or powdery ash requires care in the

*This is the third and last of a series of articles on this subject; the two preceding appeared in the September 15 and the October 1 issues.

design and construction of the combustion chamber. The flame must be short enough so as not to heat the bottom of the chamber above the fusing point of the ash and yet be long enough to get the zone of maximum temperature of combustion well down into the chamber so as to fill up the combustion space and have combustion completed before the gases enter the boiler tubes.

Entering velocity of the coal and air mixtures should be correct in order to give the proper length of flame. The amount of ash formed in the combustion chamber is relatively small. With an ash content of 10 per cent in the coal, we have 200 lb. of ash per ton of coal burned; of this 200 lb., about 25 per cent is collected in the combustion chamber bottom, or 50 lb. per ton of coal burned. This ash is removed in the usual way by raking out, or dumping into an ash conveyor.

About 25 per cent of the ash, or 50 lb. per ton of coal, is deposited on and below the boiler tubes. This ash is extremely fine and is removed as dust. The balance of the ash, or 100 lb. per ton of coal, is carried up the stack and dissipated in the atmosphere and so far has never been found to be a source of complaint, the fine dust apparently being spread out and carried long distances.

In order to get proper ash formation by keeping the bottom of the combustion chamber cool, some furnaces are built with a water screen about 3 ft. from the bottom of the chamber. This water screen consists of a row of boiler tubes across the bottom of the chamber, spaced about 12 in. apart. The screen forms part of the boiler heating surface and a rapid circulation of water is kept up, 1 sq. ft. of screen surface being equivalent to 1 boiler hp. The ash is collected below the water screen and removed several times a day.

Another method of keeping the bottom of the combustion chamber cool is to circulate air through the lower side walls and under the bttom of the ash floor. This preheated air is drawn through the hollow walls by an exhauster and delivered to the coal feeders or the unit pulverizer, where the pulverized coal is picked up by the air and carried to the burners. This preheated air by evaporating the free moisture in the coal prevents caking of coal on the inside of the unit pulverizer and contributes to smoother running of the machine.

Ash with a high fusing point will naturally give less trouble than a low fusion ash. The softening temperature of ash from bituminous coal from tests of the Bureau of Mines, Washington, show a range from 2060 to 2900 deg. F. These results were obtained by W. A. Selvig and A. C. Fieldner, when testing numerous samples of bituminous coal.

Low Grade Coals May Be Burned Economically

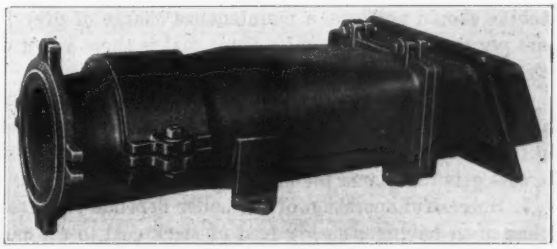
One great advantage of burning pulverized coal is the ability to utilize coals of low B.t.u. value and with proper furnace design, high or low fusion ash. Coals high in sulphur can be burned better than with any other method of firing, the sulphur being converted into sulphur dioxide and carried off with the hot gases of combustion without chilling, or condensation of sulphur monoxide upon the boiler tubes; that is, there is no destructive effect on the tubes by sulphuric acid.

Almost any grade or quality of fuel, anthracite, bituminous or lignite can be burned successfully in pulverized form. At the present time it is estimated that the annual consumption of pulverized coal in the United States is upwards of 35,000,000 T. per annum, this consumption being spread over metallurgical furnaces, cement kilns and steam power plants.

While experience has shown that for metallurgical work high volatile fuels are necessary, for the firing of steam boilers, low volatile fuels may be, and are being used. At the River Rouge Plant, Detroit, of the Ford Motor Car Co., coal of the following average proximate analysis is burned:

Moisture, per cent as fired	6.0
Ash, per cent	15.0
Volatile, per cent	12.0
Fixed carbon, per cent	72.0
B.t.u., per lb	13,000
Per cent through 100 mesh	90.0
Per cent through 200 mesh	70.0

Fuels having a volatile content of only 5 per cent are being burned successfully and at the Susquehanna Collieries Co., at Lykens, Pa., 12 water-tube boilers are being fired with anthracite culm.



MIXER BUILT IN AS A PART OF THE BURNER INSURES UNIFORM DENSITY OF THE COAL AND AIR MIXTURE

Lignite and brown coal have been burned with high thermal efficiencies in a pulverized form keeping in mind the calorific value and the moisture content as fired. At the plant of Morris & Co., Oklahoma City, some tests conducted by engineers from Swift & Co., Chicago, showed an evaporation of 4.84 lb. of water per pound of coal as fired, and 5.375 lb. of water per pound of coal from and at 212 deg. F. The analysis of the coal burned being as follows:

Texas Lignite Run of Mine (Hoyt)

	As Received	As Fired
Fixed carbon, per cent	31.36	37.58
Volatile matter, per cent	23.71	30.11
Moisture, per cent	33.13	19.59
Ash, per cent	11.80	12.72
Heat value, B.t.u.	6722	7928

It has been demonstrated that coal containing 27 per cent moisture and 54 per cent ash, can be pulverized and burned with a unit machine by adding a small amount of liquid fuel. By adding fuel oil for instance, at the rate of 1 lb. per T. of coal this has been accomplished.

At the Philadelphia Power Station of the Lambton and Hetton Co., England, coal of the following analysis is burned under a Babcock and Wilcox 600 hp. boiler: Moisture of 0.93 per cent, volatile matter 24.67 per cent, fixed carbon 41.24 per cent, ash 33.16 per cent, calorific value 9550 B.t.u.

The principal reason for pulverizing this coal was that hand firing or stoker firing did not give satisfactory results as disintegration of the coal did not take place, and it was quite usual for a lump to leave the stoker in the same shape as when originally charged.

On test an overall efficiency of 74.1 per cent was obtained with boiler and superheater, and by adding the economizer efficiency, the overall efficiency was over 80 per cent. This data was published in the "Iron & Coal Trade Review," England, Aug. 4, 1922.

Characteristics of a Good Unit Pulverizer

In selecting a unit pulverizer for boiler work, the following features should be given careful consideration.

1. Fineness of the coal should run from 65 to 75 per cent through a 200-mesh screen, and the machine should be capable of doing this over as long a period as possible.

2. The power consumption should average about 25 hp. per ton of bituminous coal ground with a free moisture content of from 5 to 8 per cent.

3. While the maintenance figure is a variable, a good machine should not have a maintenance charge of over 10 cents per ton of coal ground. Some makes show a cost of 5 to 8 cents per ton extending over a long period.

4. Beaters wear rapidly and affect the fineness of pulverization. A good machine should be capable of grinding from 1000 to 2000 T. of coal per set of beaters, before the coal gets too coarse for proper firing.

5. Successful operation of the boiler depends to a great extent upon having a steady feed of slack coal to the pulverizer. A good feeder should have a range of feed that will fully take care of the load on the boiler, particularly where the load is variable and running from rating or below, to say, 250 per cent of rating.

6. Most unit pulverizers are of the horizontal type, some take up more space than others. Vertical pulverizers take up less space and there are at present few on the market. However, developments are being made on this type and vertical pulverizers will be attractive to many prospective users.

7. Good air regulation should be provided and suitable mechanism arranged so that the coal feed and air supply can be controlled automatically, by steam pressure, to take care of fluctuating power requirements.

8. Design and construction should be such that the machine can be opened up and changes made in a minimum of time to the beaters and liners or such parts subject to attrition by the moving coal through the pulverizer. It is advisable also to carry plenty of spare parts.

9. Most pulverizers have no provision to take up wear on the beaters and liners without shutting down to open up and make the necessary renewals. This is one of the mechanical limitations on present pulverizers and no doubt as improvements in construction are made this adjustable feature will be taken care of from the outside without having to shut down and open up the mill.

10. Approximate figures only can be given as to cost. A machine having a capacity of 3500 to 4000 lb. of coal per hour, ground to 65 to 75 per cent through 200-mesh and 5 per cent moisture content will average in cost about $4000, not including the motor or magnetic separator.

Complete combustion of the fuel, and rapid ignition are usually obtainable with the unit pulverizer. The thorough mixing of the air and fuel in the machine promotes good combustion, eliminates smoke from the stack, and there is little or no combustible in the ash.

Positive control of the air and coal can be obtained to maintain proper furnace temperature, good CO_2 and varying load demands on the boiler can be met quickly and satisfactorily.

There is little equipment to get out of order and, by carrying the spares necessary to replace parts subject to the attrition of the coal, shut-downs can be reduced to a minimum.

Cleanliness in the boiler room is obtained as the machines can be made practically dustproof and the pulverizing action is such that air and dust are drawn into the machine and not blown out except through the burners to the furnace. Good boiler efficiencies can be obtained. Tests from unit pulverizers will compare favorably with the excellent results obtained in the central station plants using the more expensive type of central coal preparation plant.

Space requirements and first cost of the equipment are both low and the labor problem is greatly simplified. Good boiler efficiency, mechanical simplicity, flexibility and ease of control will justify the adoption of unit pulverizers in many plants now fired by hand or stokers. The labor problem is greatly simplified.

When starting a new air compressor, turn the machine over a few times by hand to see that it works freely and that everything is clear. This is an important precaution, as accidents have resulted by starting a newly erected machine without first having turned it through at least one revolution to see that everything is clear.

After compressor is in proper condition, turn on a full supply of cooling water. The compressor should be run for a while at reduced air pressure and should be closely watched at the start, giving particular attention to the crank case. Even though the compressor has been carefully cleaned there is sure to be more or less dirt remaining, which will be washed out by the circulation of the oil. All of this dirty oil must be removed. The bottoms of the crank cases should again be wiped out and all sediment removed. A fresh supply of oil should be put in, which will remain clean for a longer time but when this also becomes dirty it should be removed. After the compressor has been running for a while, it should not be necessary to change the oil oftener than once a month.

Specific problems in coal beneficiation which come to the attention of the Department of the Interior and which are considered to be of general interest, rather than an individual operator's special problem, are investigated by the Central District experiment station of the Bureau of Mines, Urbana, Illinois, in order to further the better preparation and more conservative use of fuel. In these investigations samples of the coal in question are examined in order to determine the nature of the impurities and the improvement that may be expected in treating the coal by a cleaning process. Tests are being made with the pneumatic table on a number of Eastern and Central District coals to ascertain the effectiveness of this method of treatment and its suitability for different types of coals. A general study of the dry cleaning process is being made in an effort to apply such methods in coal preparation work and to develop a simple method of treatment.

Procedure for Alining Power Equipment

PROPER ALINEMENT CANNOT BE OBTAINED IN ONE EFFORT, A CHECK MUST BE MADE WITH THE UNIT IN OPERATING CONDITION

MOST COMMON among the causes of unsatisfactory engine room equipment performance is misalinement. The results of inferior conditions of alinement do not vary greatly, except that they become more complex and far-reaching the longer such conditions exist. These results are vibration, burned out bearings, bent shafts,

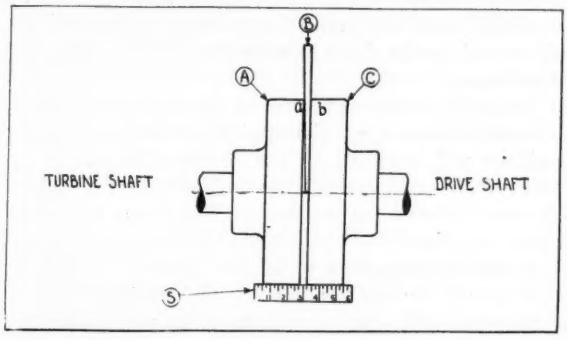


FIG. 1. METHOD OF MAKING PRELIMINARY ALINEMENT

crystallization of material in the revolving elements, all resulting in breakage of shafts, couplings and other rotating parts and this often when the stresses in these parts appear practically negligible. No amount of petting, overhauling and renewal of parts on a machine which is out of alinement and giving trouble will remove the difficulty unless the misalinement is corrected.

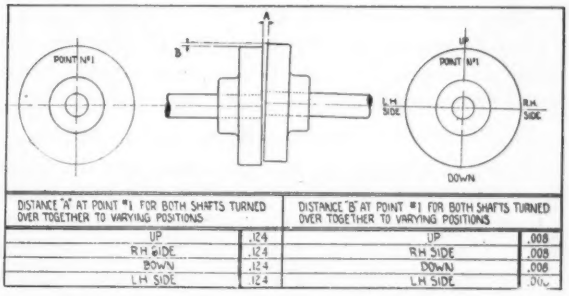
When a machine is in correct alinement any two shafts which are coupled together have their axes in the same straight line. Secondarily, casings, cylinders, frames and bearing pedestals are so placed that the correct clearances are obtained between them and the reciprocating parts, revolving shaft and rotor parts. All units completely assembled at the factory are correctly alined when assembled and are tested before shipment. Also the majority of such units have all parts mounted either upon a continuous one-piece baseplate or upon a two-piece baseplate rigidly bolted together.

Notwithstanding the careful assembly of the parts at the factory and the use of continuous baseplates, it is always necessary to re-aline the unit after placing it on the purchaser's foundation. This is due to the flexibility possessed by even the most massive of cast-iron baseplates and also to the impossibility of exactly duplicating on the customer's foundation the conditions which were in force during the assembly and test at the factory.

When installing a new unit it should be placed in the correct position on the foundation and supported at intervals by steel blocks about 1 in. in thickness. Baseplates are generally provided throughout their length and breadth with several sets of small leveling pads, the tops of which are planed off at the same time the other surfaces on the baseplate, for the support of various parts of the unit, are machined. Using a machinist's level and by means of the leveling pads just referred to, proceed to level up the baseplate by wedging up underneath it with steel wedges and tightening down the foundation bolts until it comes level at all points, both lengthwise and crosswise. Always check the level used by turning it end for end since the glass is not always parallel to the bottom. Also never read from one end of the bubble only since temperature changes alter the size of the bubble.

When the baseplate has been carefully leveled and care has been taken to make sure that the unit is correctly placed with respect to its piping and the other parts of the power plant layout, the unit may be grouted.

After the grouting has set, the alinement proper may proceed. There are several different means by which two shafts may be alined so that their axes come in the same straight line but the simplest and most accurate means is the method which makes use of the coupling flanges. Remove the upper half of the coupling housing or guard and take out all the coupling pins. By means of a short



DISTANCE "A" AT POINT "1" FOR BOTH SHAFTS TURNED OVER TOGETHER TO VARYING POSITIONS		DISTANCE "B" AT POINT "1" FOR BOTH SHAFTS TURNED OVER TOGETHER TO VARYING POSITIONS	
UP	.124	UP	.008
R.H. SIDE	.124	R.H. SIDE	.008
DOWN	.124	DOWN	.008
L.H. SIDE	.124	L.H. SIDE	.00[illegible]

FIG. 2. FINAL CHECK IS MADE BY ROTATING BOTH COUPLING HALVES

steel straightedge placed across the top of the two coupling flanges, the approximate difference in level of the two shafts may be observed. Likewise, by moving the straightedge down to the sides the approximate amount of movement necessary to bring the shafts in alinement sidewise may be seen.

By means of a tapered thickness gage, or a set of common feelers, inserted between the faces of the coupling flanges at various points around the circumference, the angularity of the two shafts may be judged. Proceed to insert or remove shims from different parts of the unit, at the same time making the required sidewise adjustments, so as to bring the faces of the two coupling flanges equidistant at all points as measured by the thickness gage and so as to bring the circumferences of the two flanges in line at the top, sides and bottom as measured by the straightedge.

This method of alinement is preliminary only and inaccurate in that it does not take account of the possibility of the coupling faces not being machined at right angles to the axes of their respective shafts and also of the possibility of the outside circumference of the coupling flange being turned eccentric to the axis of its shaft.

After alining roughly as outlined in the preceding paragraph, connect up the steam and exhaust piping, warm the unit up and run it long enough to make sure that actual and constant operating conditions have been obtained.

The final alinement must be made with the whole installation subjected to actual operating temperatures. Shut down the unit, insert one coupling bolt without its bushing to insure both shafts turning over together and always in the same relation and mark some point on the circumference of the flanges.

Turn the shafts over together to several different positions and measure dimensions "A" "B" at point No. 1 for each of these different positions and record the readings in a tabulation similar to that shown in Fig. 2. If dimension "A" is the same for all the different positions of point No. 1 then the two shafts are parallel. If these different readings of "A" are not the same then the shafts are not parallel and the parts of the unit must be shifted until these readings come the same for the different positions. Similarly if all the readings for dimension "B" are the same the ends of the axes of the two shafts meet but if these readings are not the same, the axes do not meet and the relative positions of the parts of the unit must be changed until they do meet. The alinement must be altered and rechecked until the various readings taken for dimensions "A" and "B" come respectively the same. A maximum variation of 0.004 in. might be allowed in either of these dimensions but if it is possible to eliminate this variation it should be done. In no case should the variation be more than 0.004 in.

Unit Must Be Dowelled After Being Alined

After a satisfactory alinement has been obtained, insert the coupling bolts and operate the whole unit for a period of time long enough to bring temperature conditions constant. Then shut down, remove the coupling bolts and check to see if the alinement is still satisfactory. If it has not changed it may be considered permanent and the various parts of the unit should then be securely and carefully doweled to the baseplate to prevent shifting. If the alinement has changed during the trial run, additional adjustments and trials must be made before dowelling the unit.

Dowelling the parts of the unit to the baseplate is exceedingly important. Correct alinement cannot be maintained unless the various parts are held in their respective locations by carefully installed dowels. After placing a unit in regular service, even though it was carefully alined and dowelled before so doing, the alinement should be checked at reasonable and stated intervals.

Small center crank engines are sometimes furnished with the generator base when ordered, with a machined surface for attaching to the engine subbase. On larger center crank units and on side crank units the generator base or shoes, when ordered, are not attached. If the generator base is of the attached type it should be securely fastened to the engine subbase after cleaning off the adjoining surfaces.

Cast-iron subbases on the small sized units and on some of the larger sized units are of the high type, that is, 16 to 20 in. high. On this type it is preferable to line up and grout in the engine subbase without superimposing the engine bed. On the larger type units where the low subbases, 8 to 10 in. high, are used, it is preferable to set the engine bed on its subbase and bolt the two together snugly. Where no subbase is furnished, the engine bed itself, of course, is lowered down over the bolts.

On small units where there is no chance of springing the bed out of level, three wedges should be sufficient. On the larger units good judgment should be used as to the number of wedges to be inserted. Wooden wedges should not be used on account of the danger of their swelling when moistened by the grout. The least number of wedges which can be used without sacrificing good support is to be preferred on account of simplifying the leveling process.

The base or bed can then be leveled up and should be checked carefully in both directions, that is, parallel with the shaft and parallel with the center line of the engine. Proper allowances should be made for grouting in as shown on the foundation plan and the height of the shaft above the floor should also be checked together with the allowances which will result for grouting in the generator subbase and for the shims between the generator stator and its subbase.

Projection of the center line of the shaft will generally be found indicated on the engine subbase and similar markings will be found on the generator bases. A line should be stretched across these to obtain the approximate alinement between the two bases. The center line of the engine will usually be found scribed on the top or edge of the engine subbase from which the distance through the center line of the stator, scribed on the generator base, can be measured and checked and made in accordance with dimensions shown on the foundation plan. When these dimensions have all been carefully checked and found to agree in all respects with the plan, the level of each base should again be checked before grouting in.

Surfaces Which Come Together Must Be Clean

After grouting the subbase, it is then ready to receive the engine bed. Be sure that the top of the subbase is perfectly clean, likewise the bottom of the engine bed. The iron wedges are then removed. Insert the dowel pins and then pull down on the studs, holding the two together firmly.

After placing the bed, the cylinder support, if one is used, should be wedged into position to bear against the cylinder with moderate pressure and to relieve the weight of the cylinder and piping which may be hung later. Care should be taken that there is no clearance between the cylinder and support and also that the wedges under the support are not driven in too hard to put undue pressure on the cylinder.

To aline the shaft on center crank engines, the bearing boxes of which are quartered, place the shaft in approximate position in the main bearing gap, slide the generator stator over the end of the shaft and place in approximate position, making sure that the rotor clears all points on the inside of the stator. Then place the outboard bearing pedestal in position, slacking off all adjusting screws. To support the outer end of the shaft, slip the outboard bearing box over the end, lower the adjusting screws until the box rests in the bottom of the housing. Then if a balance wheel is furnished, place it in approximate position on shaft. Then red lead the top of the shaft journals and rotate on the bottom quarters of the main bearings.

By raising and lowering the outboard bearing with the adjusting screws, a perfect fit can be obtained on the two main bearing bottom quarters, which will wipe clean the red lead. This insures perfect levelling of the shaft with the bed. Then place the three-quarters of each bearing and lower the main bearings caps. Bolt down the latter snugly with the bolts and studs provided and also pull

down to a tight sliding fit the two sides quarters and top quarter by means of the set screws provided in the caps.

Then force the shaft snugly against the quarters on the cylinder side and pull up the crank end quarters by means of the set screws at the end of the bed. In doing this, jar the shaft slightly with a bar so that it will take its natural position. Keep the side screws on the outboard bearing loose to prevent any bending or twisting of the shaft. After all side clearance is taken up on the shaft in the main bearing, adjust the side screws on the outboard bearing, so that it is held rigidly in place. Then set all lock nuts. In this manner the outboard bearing is self-alined with the shaft which prevents any possible twisting or flexing of the shaft in operation.

After the shaft has been perfectly alined the generator stator should be set to give equal clearance at all points on the rotor periphery. The generator shoes or base are then lined up with the stator and after being properly set as described above, can be grouted in place and bolted down.

It Is Often Advisable to Run a Line Through the Engine

With direct connected side crank units the shaft can be alined by fitting it to the main bearing in the same manner as that described for center crank engines. It is recommended, however, that in order to insure perfect alinement that a line be run through the engine proper and that the shaft be set to this line. The method of doing this is illustrated in Fig. 3.

Before placing the shaft, it is best to lower the lower half of the governor wheel in position as it is inconvenient to place the lower half of the wheel after the shaft is in place. Also place the pedestal of the outboard bearing in position and the lower half of the bearing. Then place the bottom quarter of the main bearing and also the cylinder quarter in position. Place the generator stator in approximate position and then also place the shaft and rotor. Obtain the level of the shaft by fitting it squarely to the bottom quarter of the main bearing, raising and lowering the outboard bearing until a perfect fit over the full length of the bottom quarter is obtained. The best way to do this is to smear the journal with fine red lead or prussian blue and rotate the shaft slowly so that this is wiped over the whole length of the journal. This can be further checked by the use of a good spirit level.

Next place the side quarters of the main bearing box and the adjusting wedge and obtain an approximate alinement with the engine by fitting to the cylinder quarter in the same manner as described for center crank engines. Whenever a change of position in the shaft is required, the outboard bearing should be shifted to give the proper alinement. When running a line through the engine the crank pin should be below the line. After the line has been carefully checked, the crank pin should be brought up to the line, near either dead center and checked, to see that the line divides it equally. If not, the outboard bearing should again be shifted to make the division equal. Then turn the crank to the other dead center and check again.

No Kinks Must Be in the Line Through the Engine

This line should consist of a fine piano wire, perfectly free from any kinks or bends. It is an important precaution to see that the line is not distorted or bent in any way and that it has not been wound on too small a spool.

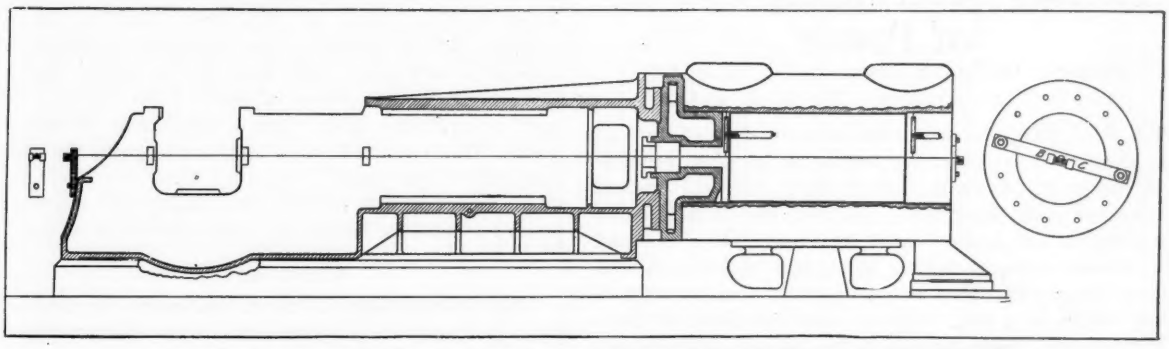


FIG. 3. IT IS OFTEN AN ADVANTAGE TO RUN A LINE THROUGH THE ENGINE

If a good straight piano wire is not available, it is preferable to use a fine silk cord or a fish line. The line is always run through the engine with the cylinder and front cylinder head in position and with the piston, back cylinder head, connecting rod and crosshead removed. The support for the line on the crank end is made with sufficient spring to keep the line tight and is held with a single cap screw so that it can be tapped sidewise for adjustment.

Setting of the line is made by means of a tram to the counterbores on both ends of the cylinder. The line should never be set to the cylinder bores. A tram equal to the radius of the cylinder is used to measure the distance from the cylinder bore to the line. The tram is held in one hand and the index finger and thumb of the other hand are held lightly on the wire adjacent to the support. The line is made central up and down by measuring with the tram from the top and the bottom of the cylinder and lined up sidewise by measuring from the two sides to the center.

When the line is nearly equally distant, the length of the tram can be shortened slightly, so that it barely touches the wire and the relative intensity with which it then touches the wire can be determined accurately only by feeling the wire with the other hand, as described above.

When this adjustment has been made on the head end, attention is turned to the crank end. This is centered in a similar way, the tram being held by a handle to reach into the cylinder and the frame end of the wire is moved by a second man as instructed by the man manipulating

the tram. Both ends must be checked several times to be sure that the line is correct. On bored guide engines, after setting the wire to the counterbores of the cylinder, use a similar tram in the crosshead guides. This will give the vertical center position of the line.

After the wheel bolts have been shrunk in place the alinement of the shaft should be rechecked as the weight of the wheels, particularly on the heavier side crank types, may cause a slight disturbance in the original alinement. The air gap of the generator stator should also be checked over again and readjusted if necessary by means of shims or shifting of the stator. The dowels in the engine base can then be driven home. Any parts, such as generator base, outboard bearing, subbase, cylinder support or other parts which have not been grouted in can then be completed and bolted down snugly.

Factors Determining Source of Power

PROGRESS IN POWER GENERATION LIES IN DEVELOPING ALL SOURCES. BY C. A. JOERGER

IN THE minds of some there seems to be an idea that the future in power engineering is one of superpower stations only. A great deal is being said and written nowadays about superpower; in fact, the term is being overworked and leading many to believe that a new and mysterious thing is coming along that will cut in half their power bills. That is not the fact. The problems of the future, for a long while, in power are along all lines, hydroelectric, interconnected power, isolated stations, superpower and oil-engine stations.

Manufacturing plants are the large power consumers, but power cost is but one of many factors in determining the organization and location of a manufacturing plant. There are at least seven limiting factors in the organization of such a plant. They are demand, fluid capital, materials, labor, transportation, equipment and power. It is not the object of this article to go into detail of each one of these items, it is simply desirable here to point out that power is but one of the limiting factors entering into the organization of a manufacturing plant. Too often people seem to think a certain excellent power site is going to waste but if they would investigate the proposition, they would soon learn that because of the inability to fulfill the above-mentioned factors manufacturing plants can not locate in the vicinity of the power plant site.

Cost of Future Power

Station cost of a kilowatt-hour is about one cent today, whether steam or hydro driven. Assuming power drawn for 300 working days of 10 hr. each, one cent per kilowatt-hour is equivalent to $22.36 per horsepower-year. This is merely a good average figure for a first class large steam turbine or hydro driven plant. First class reciprocating steam engine plants probably produce their power for about $30 per horsepower-year. Added to the station cost is the cost of distribution and stand-by charges because of the yearly load factor.

In the case of the steam driven plant the cost of fuel, labor and materials is certainly in general upward. In case of the hydro driven plant the machinery, structural material and labor costs have been going up. The efficiency of the hydro unit is about 95 per cent now, hence much can not be gained along this line. The steam plant has reached high efficiencies and any gain along this line will merely offset increasing costs.

Hence there is no real reason to expect cheaper power in the future, neither from the hydro driven plants nor from steam plants.

Interconnected Power Systems

Interconnection of power systems is a better arrangement than superpower stations. By this scheme steam power plants and water power plants at widely separated points deliver current into different points of the same line. In this way there is power and transmission economy. Power can be interchanged to suit the variable power developed by the water conditions of the hydro plant. For a long time this will be the line of development. It is the natural and logical way.

There is another admirable feature to this system and that is the possibility of stopping the undesirable concentration of industries in a few cities. It is best for the citizenship of our people to have industries established in small cities and villages like those of the Middle West or New England. A network of power lines reaching the small communities gives them a cheap and dependable power. This gives industries a chance to go to the small cities where real estate is cheaper, taxes are lower and where the wholesome conditions of family life and social privileges make for better relations, hence fewer strikes.

Water Power

Many persons seem to think that every waterfall is a fine opportunity for a hydroelectric plant. Before anybody undertakes the development of a hydroelectric plant it is necessary to find about $200 per hp. to get it ready to produce power. It is necessary to find somebody who will use this power and what price he will pay for it. Also how dependable is the water supply year in and year out.

Hydroelectric development is wise and desirable. No one can question that it is better to utilize water power that is going to waste than to exhaust the coal and oil supply. It is certainly better to scatter industries over the country than to crowd them into large cities. It is also essential that the public appreciate that water power does not necessarily mean unusually cheap power.

In water power as in all other cases it is necessary to take into consideration all the factors that enter into the problem.

Steam Power

Since reciprocating engines deliver about 15 per cent of the energy in the fuel and large turbines about 35 per cent, many consider this an excellent field for improvement. There is a possibility of course but it is a difficult task. Just now the mercury-vapor turbine in combination with the steam turbine is holding our attention. Also a steam turbine outfit with steam at a pressure of 1000 lb. per sq. in. or more. Perhaps the next great step will come along these lines, perhaps from improvements in long distance electrical transmission.

One place where steam units of all description will long hold their own is in manufacturing plants where exhaust steam can be used for process work. Nothing can displace a steam unit in this case.

Future power development therefore seems to be along all lines. A great deal is being said of the hydroelectric power that can be developed from the St. Lawrence River.

It is supported to amount to 5,000,000 hp. That is enough to supply the whole eastern district of New York and New England. But it will probably not soon be done, as it is necessary first to determine the price that would have to be charged consumers and how these prices compare with the price of power from other sources in various sections of the country covered. The whole problem is one of economics and the development will not be along one line but along several lines depending upon the limiting factors involved in each case.

Chlorine Keeps Condenser Tubes Clean

By C. H. S. Tupholme.

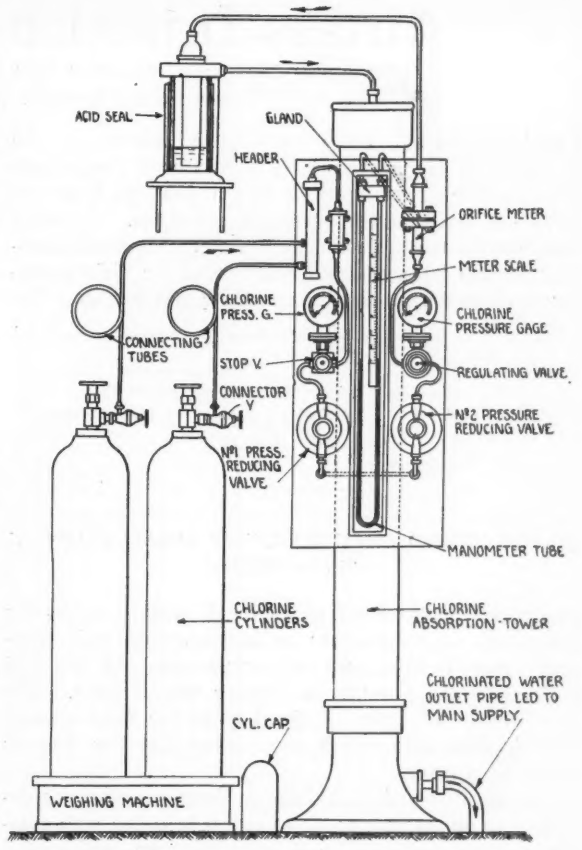
RECENTLY there has been developed a process for the continuous and automatic treatment of cooling water with a measured trace of chlorine gas, generally not over one part per 3,000,000 of water, to prevent the fouling of condenser tubes and other cooling surfaces with deposits of living organisms. The device is known as the Chloronome. As far as the steam turbine is concerned what this means from the point of view of fuel economy is well illustrated by the fact that one London power plant is saving about $6000 per yr. on a 6000-kw. generating set, by the reduced steam consumption due to the continual maintenance of a high vacuum.

It is known that chlorine is a powerful antiseptic and the process described here is essentially one of semi-sterilization, preventing the growth of living organisms which in the usual course constitute a tenacious and non-conducting deposit on the inside surface of the condenser tubes, thus also acting as a trap for mud and so still further reducing the rate of heat transmission.

In present general condenser practice the tubes have to be cleaned out by hand with rods and brushes, sometimes as often as once a week, which means in the first place a serious loss of time in the operation of the condenser and often necessitates the installation of an extra standby unit. Hand methods are costly, the cost for the 6000-kw. set already mentioned being nearly $150 per yr.

This Chloronome apparatus for large volumes of water, say 2,000,000 to 75,000,000 gal. per 24 hr. is known as the manometer type and it consists of a control board arrangement connected to cylinders of liquid chlorine as shown in the accompanying sketch. The panel includes a filter for the chlorine and two pressure reducing valves in series. The first of these valves reduces the pressure of the gas to about 30 lb per sq. in. while the second controls and reduces the pressure to 10 lb. A system of gages and meters are also provided to indicate the amount of chlorine passing and to regulate the exact quantity of chlorine used.

Chlorine gas bubbles through a seal of concentrated sulphuric acid which prevents any moisture passing back into the apparatus from the water. It then goes into a vertical absorber, which is a glazed earthenware tower filled with pumice stone, over which water trickles from the top. The gas is completely absorbed and the water which runs out continuously at the bottom is a dilute solution of chlorine which passes direct to the main supply of the cooling water at the pump suction. The use in this way



APPARATUS FOR INJECTION OF CHLORINE INTO WATER

of chlorine gas, which is a pure standard product and its absorption in a small portion of the water before addition to the condensing water is one of the main features of the process.

As already stated, the amount of chlorine, which is predetermined by experiment, rarely exceeds one-third of a part per million, even when the water is contaminated by sewage. There is no damage done to the piping, pumps or other sections of the circuit as the quantity of chlorine is too small. The process has already been adopted with satisfactory results at over 20 power stations in England.

WHEN A TURBINE is opened up for inspection or repairs, the job should be supervised by a skilled man sent by the manufacturer,—at all events until the operating engineer has become thoroughly trained in such work; and when the machine is large or complicated, the manufacturer should always be consulted before it is opened up. In removing and handling the rotor special care should be taken to avoid injury to the blades and other delicate parts. At the time of such inspection the oiling system should be completely cleaned out and filled with new oil. After the parts have been assembled again, and before admitting steam to the machine, the rotor should be turned over by hand, to see that it does not bind or rub, nor meet with serious resistance to rotation from any other cause. Inspections of the kind indicated should be made at least once a year, and at such times every part of the turbine should be carefully examined for defects.

Airless Injection Oil Engines---II*

INDIRECT INJECTION THROUGH USE OF DIVIDED COMBUSTION CHAMBER IS FEATURE OF WORTHINGTON ENGINE. BY H. F. BIRNIE AND R. C. BAUMANN

PRACTICALLY every oil engine offered on the market today has some individuality of design connected with its fuel injection system although there are few basic variations in operating principles. It would seem that the manufacturers have preferred to avoid classifying engine types but rather to reserve for their particular product some designation of their own coinage. The

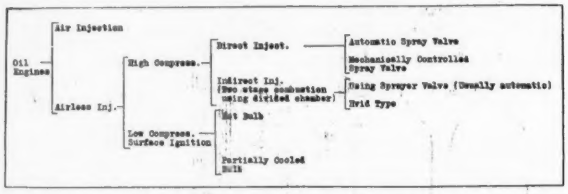


FIG. 1. GENERAL CLASSIFICATION OF AIRLESS INJECTION OIL ENGINES

prospective purchaser of an engine is soon at a loss for some basis of comparison; he is confronted with arguments favoring high and low compression, hot and cold bulbs, constant pressure or Otto or mixed cycles. The brief outline of types in Fig. 1 gives the more general classifications into which the airless injection engines might be grouped.

In the first article the De La Vergne engine was described as an example of direct airless injection with automatic spray valves. The Worthington two cycle model built at the Blake-Knowles plant of the Worthington Corp. will be chosen as an example of indirect airless injection.

On the Worthington engine the fuel pump an assembly of which is shown in Fig. 2, is operated by eccentrics and not by cams. The crosshead of the eccentric strap is guided by a pivoted link. Considerable clearance is provided between the crosshead and the pump plunger so that the crosshead does not come into contact with the plunger until the eccentric is in a position 41 deg. before upper dead center. This design avoids the low velocity spraying which would take place at the beginning of the pump discharge stroke if the plunger were to move as a unit with the crosshead. With the clearance, as provided in the Worthington and other eccentric driven pumps, the plunger is struck by the crosshead while the latter is moving at considerable velocity, hence the

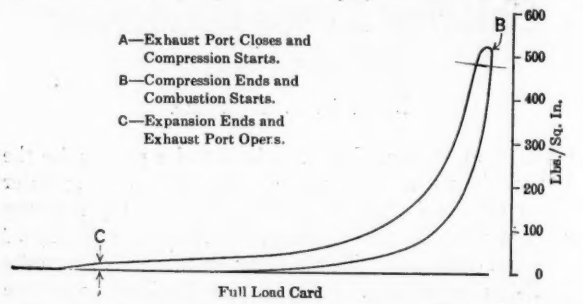


FIG. 3. COMBUSTION PRESSURE IS APPROXIMATELY CONSTANT FOR A SHORT PERIOD

first part of the oil charge is sprayed into the cylinder at as high a velocity as any other part of the charge and the atomization is practically uniform for the full period of spraying. The travel of the pump plunger is at all times constant regardless of the engine load, the delivery being regulated by the conventional bypass valve whose time of opening is controlled by the governor.

On the right in Fig. 2 is shown the timing diagram which gives a clear idea of the regulating device. The intake valve of the pump also functions as the bypass valve. As a bypass valve it is opened by a push rod which in turn is actuated by the pump plunger through a lever, an end of which rides on an eccentric shaft connected to the governor. The governor turns the shaft and thus controls the clearance between the push rod and the suction valve and consequently the time of opening of the valve. It will be noted that all oil passages in the pump are laid out with a view to avoiding pockets where air might lodge.

*The first article of the series appeared in the July 15 issue.

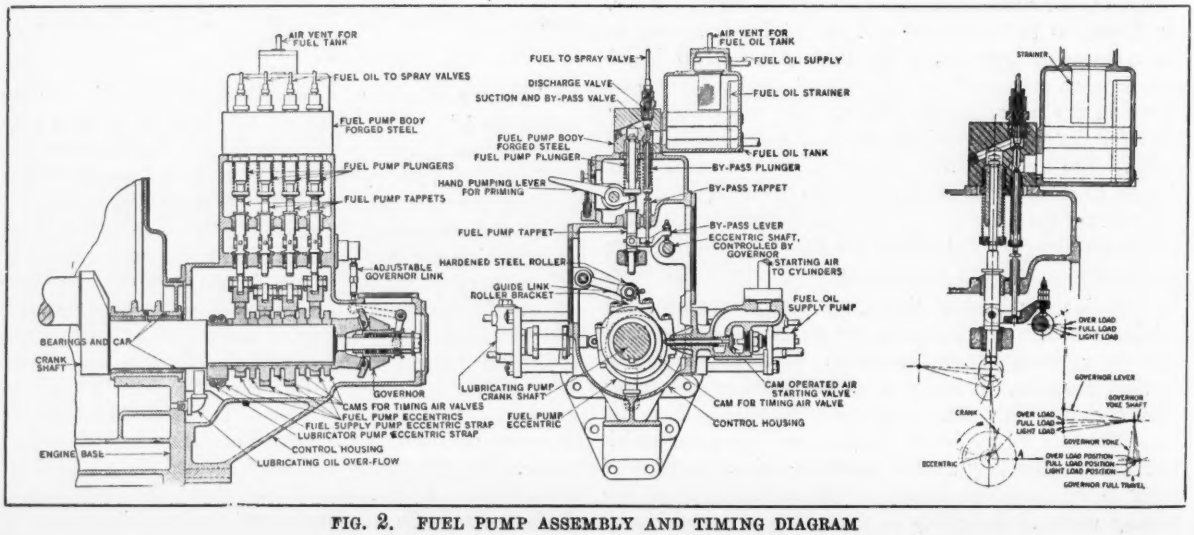


FIG. 2. FUEL PUMP ASSEMBLY AND TIMING DIAGRAM

In the divided combustion chamber system such thorough atomization of the fuel in the sprayer is not required as in the direct injection system, hence the spraying velocity and consequently the oil pressure behind the sprayer is less.

Figure 4 is a section through a cylinder with a divided combustion chamber. The chamber A receives the oil spray and it is here that the initial or pre-combustion takes place. The chamber A is not scavenged. At the beginning of compression it is filled, therefore, with hot gases remaining from the previous cycle. At the end of compression it contains a small quantity of fresh air diluted by the hot burned products of the previous cycle, the fresh unburned air charge having been forced in during the compression. The contents of the chamber A are therefore at a higher temperature than the remainder of the compressed air charge in the main combustion clearance space above the piston.

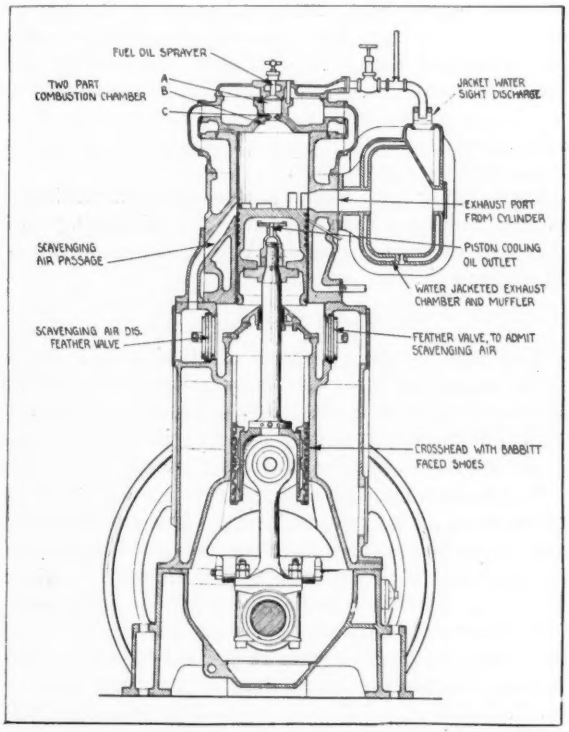


FIG. 4. SECTION OF WORTHINGTON ENGINE SHOWING DIVIDED COMBUSTION CHAMBER

When the working piston is approximately 16 deg. before top dead center the injection of fuel begins. Only a small part of the fuel charge is burned in the chamber A because of the limited quantity of oxygen available. The remainder is vaporized by the intense heat and is subsequently ejected into the clearance space above the piston by the expansion of the gases in the chamber A through the restricted opening C. The combustion is therefore progressive and its rate of propagation is partially controlled. The result is a card such as Fig. 3.

Burning which takes place slowly enough to keep the pressure approximately constant for a short period is the result of (a) decreasing the rate of fuel delivery, accomplished by decreasing the pump plunger speed as the pump eccentric nears top dead center. (b) Throttling the rate of flow from the precombustion chamber A to the clearance space B by making the connecting orifice C small.

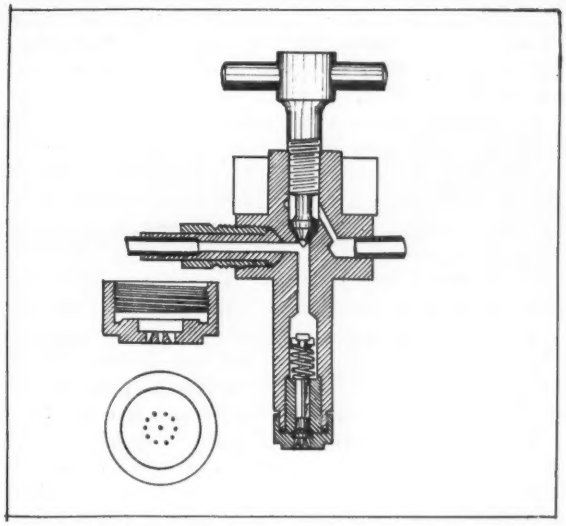


FIG. 5. VENT VALVE AT TOP IS FEATURE OF FUEL INJECTION VALVE

The advantages claimed for a combustion head with a divided pre-combustion chamber are:

(1) The atomization of the fuel charge during injection need not be so thorough as for direct injection engines, hence the oil pressures used to spray the fuel into the cylinder are less.

(2) The high peak pressures which sometimes occur in direct injection engines as the result of poor design or faulty timing of the injection are more certainly avoided. The rate of burning is graduated and gives a more nearly constant pressure card.

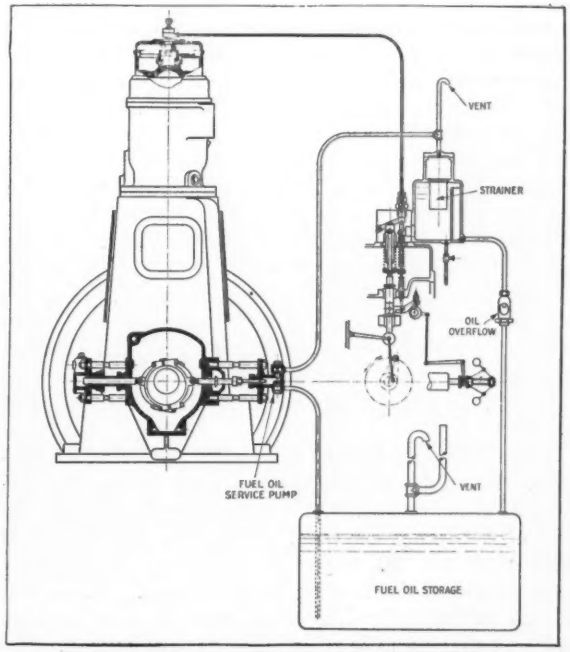


FIG. 6. ARRANGEMENT OF THE FUEL DISTRIBUTION SYSTEM

As an example of good design, the Worthington injection valve is well worth careful study. It is placed in the center of the cylinder head thus placing the check valve in a vertical position.

An excellent feature is the bleeder or vent valve at the top of the spray valve body. The bleeder is opened before starting the engine and the pump plungers are operated by hand until fuel oil, free of air bubbles, flows in a solid stream from the valve, thus indicating that all air has been expelled from the fuel lines, after which the bleeder is closed before starting the engine. Since this bleeder is placed at the highest point in the oil lines, any air which finds its way into the system during operation collects directly below its seat and may be conveniently removed by opening the vent from time to time without interfering seriously with the running of the engine.

The spray check valve is well centered by a long guiding spindle and plenty of room is provided for a substantial spring. By placing the spring before the check valve the volume of oil suspended between the closed check valve and the sprayer or nozzle plate is made as small as possible, and this minimizes the possibility of solid drops of fuel dripping through the nozzle plate between injection periods. This fuel, which would of course reach the cylinder unatomized, burns imperfectly and results in objectionable carbon deposits. The spray plate has 10 holes drilled in a circle at a slightly diverging angle and one central hole.

Figure 6 gives the fuel distribution diagram of the engine, which does not differ essentially from the arrangements shown previously.

Concrete Construction During Winter Months

POWER PLANT construction and maintenance work cannot, in most instances, wait upon the seasons of the year. It often happens that concrete must be mixed and poured in cold or freezing weather. Under this condition concrete is likely to freeze and once having been frozen it is worthless and must be replaced. Therefore before work of this kind is undertaken a general understanding must be had of the practice which will assure good concrete under unfavorable weather conditions.

In early winter, when temperatures fall below freezing during the night, the only precaution necessary is to protect concrete with canvas or other coverings. As the weather grows colder and freezing temperatures prevail continuously, the mixing water must be heated. In severe cold weather it is necessary to heat both water and aggregates. In extreme cases the mixer drum and contents must also be heated, more ample coverings must be provided and the concrete kept warm by salamanders or other heaters.

Heat hastens and cold delays the hardening of concrete. When the temperature is around 80 deg. F. concrete hardens rapidly. At temperatures below this the rate of hardening decreases. When the temperature is around 50 deg. F. process of hardening is noticeably retarded and at the freezing point it ceases. Under conditions favorable for hardening, concrete soon acquires sufficient strength to be safe against damage by frost. The warmer it is kept the sooner will it reach this degree of hardness.

On small jobs water can often be heated in tanks or kettles over a fire. Where running water is available, it may be more conveniently heated in a coil of pipe over an open fire. On some jobs live or exhaust steam is discharged directly into the water tank supplying the mixer.

Heating Sand and Gravel

Sand and pebbles or broken stone may be heated by banking them over any improvised stove, such as an old smokestack, a metal culvert pipe, or boiler shell. A stove may be improvised by building sides and back of concrete block or brick with a sheet metal cover on which the aggregates are piled. The materials are turned frequently so heating will be uniform.

When steam is used for this purpose it is often discharged directly into piles of aggregates from jets or perforated pipes. Small holes drilled along the bottom side of the pipe permit the downward escape of the steam, which rises and warms the aggregates surrounding the pipe. Under extreme conditions cooling of the materials, while in the process of mixing, can be prevented by flaps on the mixer openings and a large blow torch which directs a flame into the mixer drum.

Ice and snow must always be removed from previously placed concrete and from the forms and reinforcing steel before new concrete is placed. A good way to do this is with a steam jet.

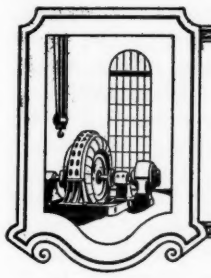
Protecting New Concrete

Walls and irregular surfaces of all sizes and shapes should be surrounded by temporary enclosures. Extreme care must be taken to see that these enclosures are weatherproof. Canvas covers already made up in different sizes especially for cold weather concreting are on the market.

Within these enclosures heat must be supplied in freezing weather. Salamanders, special heaters combining steam with dry heat and oil stoves are used, all of which are satisfactory if they provide enough warmth, combined with plenty of moisture to prevent drying out of the concrete. Care must be taken to keep these heaters far enough away from the fresh concrete to prevent premature drying out. An average temperature of not lower than 60 deg. F. should be maintained within the enclosures for at least five days. Particular care must be taken to protect small projections, such as sills, ledges, copings, corners and other trim pieces. Too early removal of forms must be carefully guarded against.

Frozen concrete is frequently mistaken for properly hardened concrete, because it has the same "ring" when struck with a hammer. A reliable test for determining whether concrete is frozen instead of properly hardened is to apply heat to the surface by means of a blow torch, or a jet of hot water or steam. If frozen, it will soften but if properly hardened it will be unaffected by the heat.

Temporary Hardness as referred to in water analysis is that part of the total hardness representing the equivalent of all the mineral salts present expressed as calcium bicarbonate which will decompose and precipitate by boiling. Magnesium carbonate although appreciably soluble is also included under this definition for the reason that when lime is used magnesium hydroxide is formed which is insoluble.—N. E. L. A. Operating Code Definitions.



ELECTRICAL MACHINERY FOR LIGHT AND POWER

Operation of Converting Apparatus---III

NOTES ON THE OPERATION OF ROTARY CONVERTERS. EFFECTS OF POWER FACTOR. BY V. E. JOHNSON

AS MIGHT BE expected from the nature of the machines, the fundamentals of rotary converter operation are closely linked with those involved in d.c. generators and a.c. motors. This similarity sometimes leads to confusion in the engineer's mind which may result in serious damage to the apparatus. It is therefore well to consider them in a class by themselves, and to be somewhat careful in judging their action by the behavior of apparently related machinery.

A rotary converter may, as we have seen, be driven externally and be used to deliver alternating current, direct current or both. Operated this way, it does not differ materially from an ordinary generator and the principles that apply to generators apply to it. If three auto transformers be connected across the rings in "Y," the neutral point may be used as the terminal of the third wire in a three-wire system. In fact, there are no essential differences between a three-wire generator and a rotary—the main distinction being that the rings in a three-wire machine are smaller, these having to carry only the unbalance in the system. A converter used in this manner, would, strictly speaking, not be a *rotary* but would really be a "double current generator."

In Fig. 1 is shown the complete connections for starting a converter from the alternating current end. Referring to this diagram, the starting operation is as follows:

a. Close oil switch. This energizes the transformers.

b. Close double throw knife switch in the "start" position.

This takes reduced voltage from the taps on the secondary of the transformer and impresses it on the a.c. rings of the rotary.

c. Note the reading of the direct current voltmeter and also observe the action of the a.c. ammeters. When the rotary has come to full speed and has dropped into step, these instruments will give a steady indication. If the polarity is wrong, as shown by a reversed reading of the direct current voltmeter, it must be corrected, using the following method:

Throw field switch up. This connects the field directly across the armature and simultaneously reverses it. The voltage will drop to zero, at which point the field switch should be thrown down. This will ordinarily cause the voltage to build up "straight"—but if it does not, the starting switch should be opened long enough for the rotary to slow down perceptibly, and then be closed again. It frequently happens that it is necessary to open the starting switch several times and also to reverse the field switch, before the proper polarity is obtained.

d. Having obtained correct polarity, the double throw switch is thrown into the "running" position and the field adjusted to secure unity power factor.

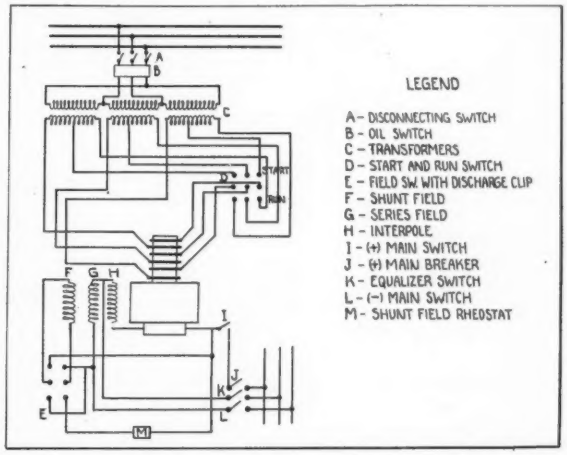


FIG. 1. COMPLETE CONNECTIONS FOR STARTING A ROTARY CONVERTER FROM THE ALTERNATING CURRENT END

e. Apply load by closing (1) circuit breaker, (2) neutral switch if the machine is for three-wire service, (3) equalizer, (4) negative, (5) positive switch. Adjust for power factor.

There are certain deviations from the system described above which must be considered. If the rotary has interpoles, it can not properly be started from the alternating current end without raising all of the brushes, except two used for voltage indication, from the commutator. There is usually an interlocking arrangement which prevents the application of a.c. voltage until the brush lifting device has been turned into the "up" position. After the rotary is in step with the right polarity, load can not be applied until the brushes have been lowered. This is an important point to remember, as failure to observe it causes the machine to draw currents far beyond the capacity of the small pilot brushes. This results in severe burning and sometimes causes flash overs.

If the converter is large, it may be necessary to use two starting taps. In that event, the polarity must be established on the lowest tap as before but the machine must be thrown on the second step before being connected to the line direct.

If the rotary converter is being started for the first time, it may rotate in the wrong direction. This is corrected as follows:

a. For a two-phase rotary, reverse the two leads of either phase.

b. For a three-phase rotary, reverse any two leads.

c. For a six-phase rotary, interchange two *pairs* of leads.

Figures 2 to 10 inclusive show transformer connections for rotaries that start from the alternating current end. Each sketch has notations on it that make further explanation unnecessary. It might be stated, however, that Fig. 2. is a two phase 4-wire arrangement for use with a 3 wire system. The switch X should be opened while starting.

In Fig. 10 of the first part of this series of articles which appeared on page 855 of the Aug. 15 issue, the connections for d.c. starting were given. The steps in starting by this method are in general as follows:

a. Close series field short-circuiting switch. This is necessary because otherwise the rotary might become unstable, under the influence of the series field.

b. Close the negative switch.

c. Close the circuit breaker.

e. Insert the synchronizing and voltmeter keys.

f. Cut the resistance out of circuit by means of the step switch or other device.

g. Adjust the speed by means of the field rheostat. The synchroscope will serve as an indicator.

h. At the instant of synchronism, close the oil circuit breaker.

i. Close the positive switch. This is in multiple with the starting switch. The rotary is now running from the a.c. end, and is connected to the d.c. bus.

j. Close the equalizer switch (if the machine is compound wound).

k. Open the series short-circuiting switch.

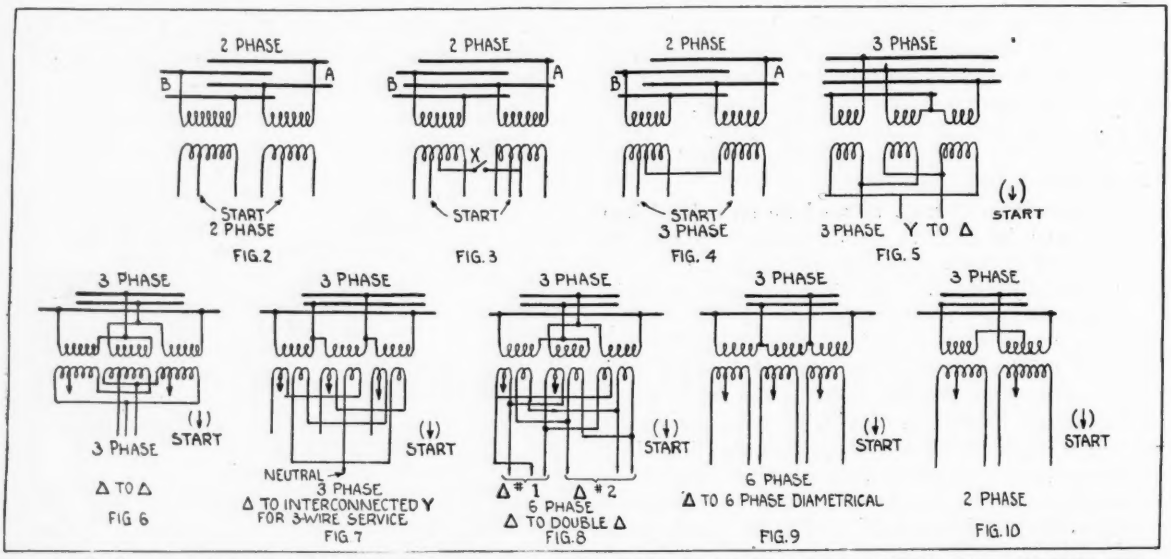
If, upon closing the step switch, the armature revolves in the wrong direction, this must be corrected by reversing either the armature or the field.

*June 1. 1924 issue. Page 600.

Inasmuch as the synchronizing of a rotary is exactly the same process as synchronizing an alternator, it follows that the same general rules apply. When starting up for the first time it is necessary to determine that the phase rotation is correct. This can be determined by following certain manufacturers rules in regard to the marking of the leads on the transformers and on the converter. It can also be determined by using lamps, connected exactly as shown in a previous article* on alternators.

Rotary converters are sometimes started by means of auxiliary squirrel cage motors, direct connected to the machine. The speeds are so designed that the normal speed of the starting motor is slightly above the synchronous speed of the converter, so that the process of synchronizing entails the slowing down of the set.

Figures 11 to 14 and 15 to 18 show a number of connection diagrams for transformers used with rotaries starting from the direct current end. These do not differ materially from those in Fig. 2 to 10, the difference being that the latter have taps for reduced voltage.



FIGS 2-10. TRANSFORMER CONNECTIONS FOR ROTARIES THAT START FROM THE ALTERNATING CURRENT END

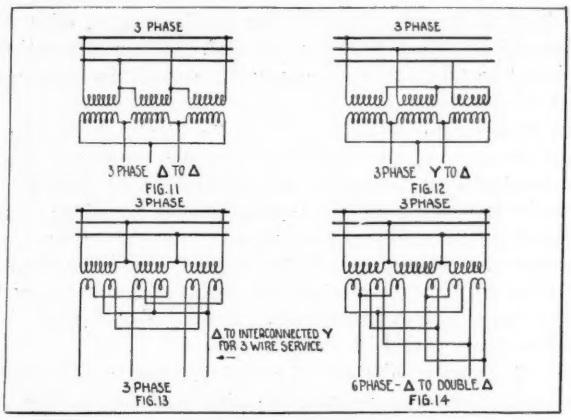
Effect of Poor Power Factor on Heating of Armature

In a rotary converter the armature conductors carry both the alternating current which flows into the rings and the direct current taken from the commutator; however, as these currents are more or less in opposition, the resultant or effective current is *not* the sum of the two but is approximately their difference.

If the internal generated voltage of the rotary, is in step with the supply circuit, the conditions would be approximately as shown in Fig. 19. The rectangular "curve" represents the direct current flowing in a conductor, while the sine curve is the alternating current. In order that the two waves may occupy positions as shown, it would be necessary to select a conductor midway between the taps which lead to the rings.

The resultant of the two superimposed curves in Fig. 19, is shown in Fig. 20. This is obtained by adding algebraically the various values of the ordinates. The effective current as is apparent is comparatively small.

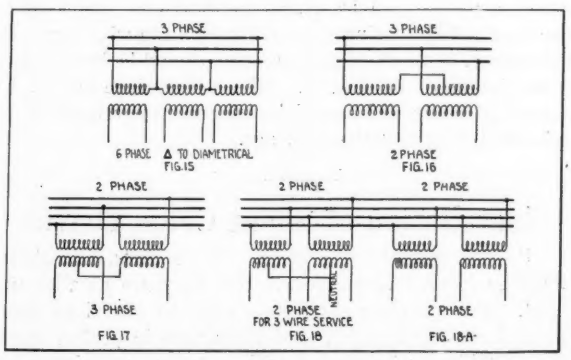
In a tap coil, the balance would not be as perfect as that in Figs. 19 and 20. The two currents would flow in a phase relation such as is approximately shown in Fig. 21, and the resultant would be that of Fig. 22. It appears



FIGS. 11-14. CONNECTION DIAGRAMS FOR ROTARIES STARTING FROM THE DIRECT CURRENT END

from this then that the tap coils receive severer treatment, than do the coils located midway between them.

If the phase relations are not those of unity power factor, the result would be still more aggravated and the heating, especially in the tap coils greatly increased.



FIGS 15-18. MORE CONNECTION DIAGRAMS FOR STARTING FROM THE DIRECT CURRENT END

The following table shows the losses in a rotary converter, compared to the losses in the same machine running as a straight d.c. machine.

Power Factor	1.00	.8
Single phase rotary	1.38	2.50
Three phase rotary	.56	1.23
Four phase rotary	.38	.94
Six phase rotary	.27	.77

The values in this table are based on sine wave values.

From this table it can be seen that six-phase rotary is preferable to one that has a smaller number of rings. For example at unity power factor, the heating effect in a three phase machine is about double that in a six phase.

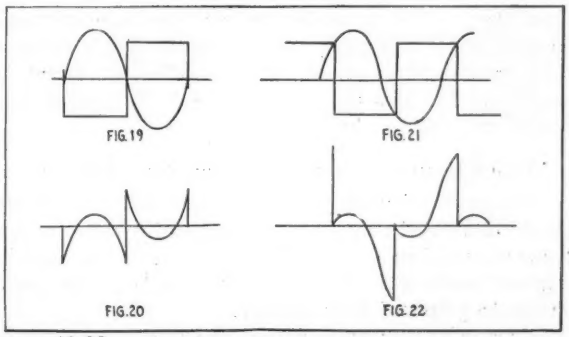
The comparative effect on the tap coils is even more marked. Thus, in a single phase rotary, the tap coils heat about 1.25 times as much as the average d.c. heating throughout the armature, while in a six-phase machine this ratio would be about .43. If the power factor be decreased to 98.5 per cent these ratios will have increased ⅓ and 2/5 respectively.

In order to show still more clearly the advantage of using a rotary converter instead of a direct current generator, the table below is given. This gives the ratio between the loads that can be carried on the same machine under the two conditions of operation.

Calling the direct current generator output 100 per cent, and basing the figures on a sine wave, a rotary can carry the following loads:

	Per cent	Per cent
Power Factor	100	80
1 phase converter	85	63
3 phase converter	133	90
4 phase converter	162	103
6 phase converter	193	114

It appears from the above, that a given machine, driven from the a.c. end at 100 per cent PF has almost



FIGS. 19-22. DIAGRAMS SHOWING THE EFFECT OF SUPERIMPOSING A. C. AND D. C. UPON EACH OTHER

double the capacity of the same machine externally driven as a straight d.c. generator.

Because of the fact that small deviations from unity power-factor produce such large changes in the heating effect, it is customary to use reactive factor meters instead of power factor meters to indicate the angular displacement. The latter are most accurate at low power factors, while the former operates better near unity.

The following table gives the power factor and reactive factor readings for a number of small angular displacements, and shows very clearly that the reactive factor meter would give the most accurate indication. With the same inherent accuracy, the deflection for a given condition would be several times that of the power factor instrument.

Angle deg.	Power Factor Per cent	Reactive Factor Per cent
0	100	0
5	99.6	8.7
10	98.5	17.3
12	97.8	20.0
15	96.5	24.0
20	94.0	34.0

For example, with an angular displacement of 5 deg., the power factor meter pointer would move only through a space corresponding to .4 per cent from unity, and probably could not be read at all. For the same angle, the reactive factor meter would read 8.7 per cent which could be easily seen.

Preparing Electrical Machinery for Installation

EXTRACTS FROM INSTRUCTION BOOK OF THE ELECTRIC POWER CLUB CONTAIN VALUABLE SUGGESTIONS

MOTORS and generators are usually shipped completely assembled ready to set on the foundations except those sizes which are limited by transportation and handling facilities. As soon as machines are received they should be kept in a dry, clean place, especially when they are put in storage and are not installed immediately. Machined parts should be slushed or painted before shipment to prevent rust and if these parts are stored for any length of time, they should be inspected periodically to make certain that rusting has not started. If necessary the machined parts may have to be re-slushed.

Particularly in the case of large, high voltage machines precautions should be taken to prevent deterioration of insulation. A safe and reliable heating system should be provided to protect the windings from alternate freezing and thawing. An electric heater with a thermostatic control is recommended when sufficient current is available. For this purpose the household type radiant heater will prove useful.

AVOID HANDLING PARTS AT LOW TEMPERATURES

Unnecessary handling of machines at low temperatures should be avoided as castings are more easily broken at low temperatures than at normal temperatures. When unpacking and handling machines the windings and other parts should be protected from damage.

As soon as they are unpacked, the machines should be thoroughly inspected to make certain that nothing has been damaged in transit and to make sure that all parts, accessories, etc., are in the proper condition. All instructions and connection diagrams received from the manufacturer should be *left with the machine.*

If the windings of a machine have been exposed to low temperatures they should not be uncovered until they have had sufficient time to attain a temperature nearly as high as that of the room in which they are to be unpacked. If this procedure is not followed the machine will sweat.

HANDLING

Traveling cranes are exceedingly convenient in handling machines. Where stations or factories are not so equipped it is desirable, except for small machines, for the user to build a crib or horse of heavy timbers for handling the machine.

Whenever practical, a complete machine should be moved as a unit. This eliminates many possible troubles with windings, armatures, slip rings, etc. Where machines are provided with eye balls, these should be used for lighting in preference to slings. When lighting motor generator sets, care should be taken not to spring the shaft by attaching the hooks or slings improperly.

HANDLING ARMATURES

When necessary to move the armature of rotor alone, the only safe method of supporting it while either moving or stationary is by slings or blocking under the shaft or by a padded cradle under the core laminations. The bearing journals must be protected so as not to mar the polished surface. The weight of the armature and field frame should not be allowed to rest on the base until the base has been levelled and grouted and the grout has had time to set hard.

The whole armature surface may be considered as subject to damage either to the bands, wedges, clips or insulation unless properly handled. Every precaution should be taken to avoid damaging any of the windings or other parts.

Commutator segments are easily displaced therefore an armature should never be lifted by passing a sling around the commutator. A spreader should always be used when lifting an armature to prevent the slings from drawing over armature band clips, collector rings, or commutator. Slings placed on the magnet frame must be so drawn as to avoid chafing the field coil insulation and the connections between coils. A rotor should never be lifted or supported by the slip rings.

If a wire rope is used for a sling, some waste or rags should be inserted between the sling and the machine to prevent marring the paint. In handling a complete machine, special care should be exercised to protect the oil gages from damage.

DRYING OUT

All electrical machinery not especially constructed to resist injury by moisture should be kept dry. If a machine has been exposed to moisture, the windings should be thoroughly dried before the machine is placed in service. Small machines can be baked in ovens and larger units can be dried by passing current through the windings. In either case, however, the temperature should be kept within a maximum of 85 deg. C. The temperature should be raised gradually and should be kept as nearly uniform as possible throughout the windings.

Installation of Silent Chain Drives

BEFORE PUTTING the chain on sprockets, the shafts must be checked to make sure that they are parallel and level. The sprockets themselves must be placed on these parallel and level shafts, so that they are in perfect alinement. This can be checked with a string or straight-edge across the face of the sprockets. Sprockets should be located as near as possible to shaft bearings. After the drive is started, it is advisable to make a second checking for alinement by observing the guide links in the chain. The wear on these guide links should be equally distributed on both sides. If more wear shows on one side than the other it indicates that the sprockets are not in alinement.

Sprocket keys should be securely in place and set screws tight. If the chain has been furnished endless, i. e., with ends joined together, the chain must be slipped over the sprockets before their installation on the shafts. If, however, the chain has been furnished with open ends, i. e. ends not joined together, as is necessary in case of line shafts and other drives where endless chain could not otherwise be conveniently installed, the chain must be placed over the sprockets and the two ends joined together.

These instructions have been issued by the Ramsey Chain Co., Inc.

Determining Pump Characteristics

Approximate Pump Characteristics Can Be Determined Graphically From Given Data. By R. T. Livingston

PUMP MANUFACTURERS supply data in their catalogs in a variety of forms—some with characteristic curves and complete data for almost any condition of head and capacity, others with tables of various forms of various degrees of usefulness. It is often useful to have the characteristic curves of a pump of preliminary estimation purposes but it is often difficult to obtain such curves. As a general rule, what is desired is the head-capacity curve for a given speed, as the shape of this curve may determine the use or rejection of the pump. Obviously, if this can be determined on a preliminary investigation much time, trouble and expense may be saved.

All centrifugal machinery obeys the same general laws of performance. These laws have been stated in a variety of forms but even at the risk of repeating what is known to all some of them will be repeated here. The law governing the relation between head, capacity and brake horsepower for a given impeller at varying speeds may be briefly stated as follows: "The total head varies directly as the square of the speed while at the same time the capacity varies directly as the first power of the speed and the brake horsepower as the third power of the speed."

This law is absolutely general, being entirely independent of the form, diameter or angles and proportions of the impeller or of the fluid handled and ceases to be true only at the "breakdown" point where the velocity becomes so high that choking occurs at the "eye" of the impeller. If an impeller is properly designed and used in the designed range, this will not occur. Shape and type of casing will make a certain small difference in the characteristic but the effect of this will be neglected in this discussion, as with any given impeller or casing or similar impeller and casing the law holds true. When a change of speed takes place, all other conditions remaining the same, the relative efficiency remains the same, that is to say, while the absolute efficiency may be higher or lower than before, the efficiency as compared to the highest efficiency at that speed, will remain the same. In other words, if the efficiency is the highest possible at a given speed it will also be the highest possible at the new speed and in a similar manner if the efficiency is 75 per cent of the highest possible at a given speed it will also be 75 per cent of the highest possible at the new speed.

These laws are of great use when considered in relation to the characteristic curves of the pump. Further, some useful approximations can be made with their use together with the use of logarithmic cross-section paper which will help show the general form of the characteristic curve of the particular pump under consideration when insufficient data is given to construct the curve.

From the above laws we can see that;

"The total head varies as the square of the quantity" or in the form of an equation;

$$H = C \times Q^2$$

where C is a constant which depends upon the design of the impeller and the particular point on the characteristic curve considered. The foregoing equation is the equation of a parabola passing through the origin (the intersection of the axes). Now it is known that a simple parabola, when plotted on logarithmic cross section paper becomes a straight line with a slope of 2 (by slope is meant the tangent of the angle that a line makes with the "X" axis). With the previous law and this rule in mind we can proceed to a consideration of the data as usually presented in the catalogs of pump manufacturers.

Pump performance data are usually found in one of three forms: First, when the points of maximum efficiency for various different speeds are tabulated and with this a so-called "100 per cent" characteristic curve, in which all data as to head, capacity, b.hp. efficiency and speed are given in terms of percentage of the rated, i. e. that at maximum efficiency. This form of curve is illustrated in Fig. 1. Second, when complete data are given at a number of different heads and for quantities rated as minimum, standard and maximum. Such a method is illustrated in Table I. Third, when for a number of different heads, quantity, speed, etc. are given for but one point. Such a table is illustrated in Table II.

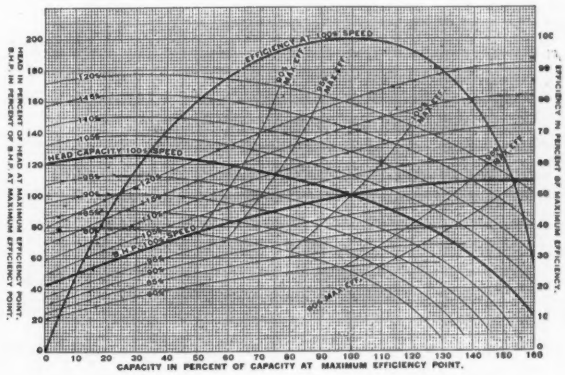


FIG. 1. TYPICAL SET OF PUMP CHARACTERISTICS

The first method of presenting data is by far the most satisfactory from the point of view of the user, as it is possible for him to estimate quite accurately the performance of the pump under almost any conditions of use both above and below its rated capacity and at different speeds and it is thus probable that he will be able to get all the information that he desires. The use of such curves hardly needs explanation but such explanation may be found in many pump manufacturers' catalogs, handbooks and in two articles on the subject of centrifugal pumps which appeared in the May 1 and 15 numbers of Power Plant Engineering.

If the data is given in the second form it is possible by calculation to obtain a close approximation of the characteristic curve, at least within the working range. Here the g.p.m., the r.p.m., the b.hp. and the efficiency are given for three conditions; the minimum, the standard and the maximum and for a number of heads. These data as they stand are hardly sufficient for the estimation of performance under varying conditions even within reasonable accuracy. If these points of head and capacity for any given pump are plotted on log. paper it will be seen that a straight line having a slope of two will pass through

each point of minimum, each point of standard and each point of maximum capacity. This shows that these points are points of the same relative efficiency. Now, if it is desired to approximate the characteristic curve for this pump we can plot sufficient of these points to assure ourselves that the slope of these iso-efficiency curves is really 2.

This has been done in Fig. 2 for both head and capacity, and brake horsepower and capacity. In the lower set

TABLE 1

Head		GPM	RPM	BHP	Eff
10	min	29.4	445	.297	25
	std	37.4	455	.338	28
	max	45.5	470	.458	25
20	min	41.6	636	.678	31
	std	53.0	644	.790	34
	max	64.4	665	1.05	31
30	min	50.9	770	1.07	36
	std	64.8	788	1.26	39
	max	76.6	813	1.65	36
40	min	58.8	890	1.51	39
	std	74.8	909	1.79	42
	max	90.8	938	2.35	39
50	min	65.9	995	2.02	41
	std	83.8	1016	2.41	44
	max	101.1	1050	3.13	41
60	min	72.0	1090	2.54	43
	std	91.7	1113	3.02	46
	max	111.3	1150	3.92	43
70	min	77.8	1175	3.06	45
	std	99.1	1202	3.65	48
	max	120.3	1241	4.73	45
80	min	83.3	1256	3.66	46
	std	106.0	1285	4.38	49
	max	128.5	1326	5.65	46
90	min	88.1	1333	4.25	47
	std	112.3	1363	5 10	50
	max	136.3	1408	6.61	47
100	min	93.0	1405	4.89	48
	std	118.3	1438	5 88	51
	max	143.8	1483	7 55	48
120	min	101.6	1540	6.30	49
	std	129.8	1575	7.55	52
	max	157.5	1625	9.75	49
150	min	114.0	1720	8.53	50
	std	145.0	1760	10.30	53
	max	176.0	1798	12.90	50

TABLE I. PUMP DATA FOR THREE DIFFERENT CONDITIONS

TABLE II. CAPACITY, SPEED AND HORSEPOWER FOR VARIOUS HEADS

TABLE II

head	GPM	RPM	BHP
10	360	450	1.85
15	426	525	3.00
20	477	600	4.33
25	478	650	5.23
30	480	700	6.27
35	480	740	7.20
40	480	785	8.30
45	480	825	9.40
50	480	860	10.50
55	480	900	11.60
60	480	935	12.75
65	480	970	13.95
70	480	1000	15.15
75	480	1030	16.40
80	480	1055	17.65
85	480	1085	18.90
90	480	1115	20.25
95	480	1145	21.50
100	480	1170	23.00
105	480	1200	24.60
110	480	1225	26.20
115	480	1250	27.85
120	480	1275	29.50
125	480	1300	31.25
130	480	1325	32.95

of curves, each point of minimum, standard and maximum capacity for each head shown in Table I is plotted. The straight lines drawn through each set of minimum, standard and maximum have slopes of two. In the upper curves the same thing has been done for brake horsepower and capacity. In the latter case, however, the slope of the lines is $2\frac{7}{16}$ to 1.

Now, for any head we have three different capacities at three different speeds. Applying the first part of the law that the quantity discharged varies as the first power of the speed we can then determine the capacities, at the efficiencies corresponding to the points of maximum and minimum capacities and at the same speed as the speed at normal capacity. Then finding the point where the correct iso-efficiency curve (which is a straight line) intersects the capacity figured projected upward, we obtain two new points which will give us points of head and capacity at the same speed as at standard capacity and at the same efficiency as at maximum and minimum capacity. This calculation mentioned above simply is;

$$Q_1 = Q_2 \times (N_1 \div N_2)$$

Where Q_1 and Q_2 are quantities in g.p.m. and N_1 and N_2 are speeds in r.p.m.

Now we have three points on the same speed. Bearing in mind the general shape of a characteristic head-capacity curve, we can pass a smooth curve through these three points, which curve will closely approximate the true char-

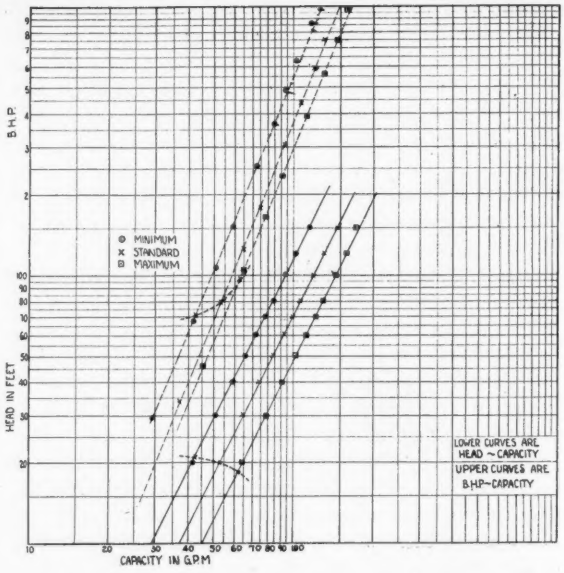


FIG. 2. HEAD-CAPACITY AND B.HP.-CAPACITY CURVES PLOTTED ON LOGARITHMIC CHART

acteristic curve and which may without serious error be slightly extended beyond the points figured. If the b.hp.-capacity curve is desired, we can proceed in the same manner as before and we shall then find that the slope of this curve is very nearly $2\frac{7}{16}$ to 1. It will probably be found simplest to plot these points to the same horizontal scale as was done in Fig. 1. Then the proper points on this curve can be determined from computation, remembering that the b.hp. will vary as the third power of the speed or the point may be obtained by projecting the capacity upward and intersecting the b.hp. curves. If desired, these curves then can be transferred to rectangular cross section paper, which is somewhat more familiar to most people and such computations may be made from it as are desired.

If the data are presented in the third manner mentioned, we shall again plot them on log cross-section paper, placing the r.p.m. alongside each point as in Fig. 3. It is seen that these points apparently bear no relation to one another other than that they seem to have been arbitrarily taken at some fixed capacity. If we now draw through each point a line with a slope of two, we shall have a number of points of different efficiencies. Now, by apply-

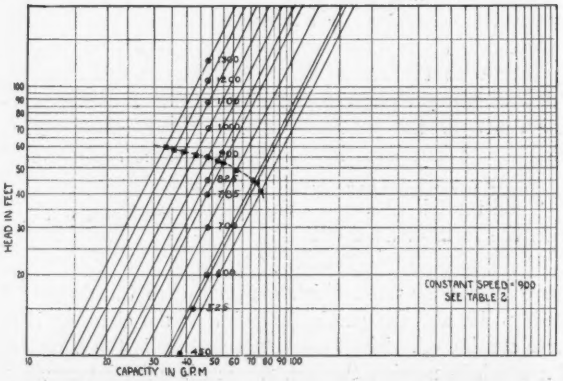


FIG. 3. CURVES PLOTTED FROM DATA IN TABLE II

ing the first part of the law as mentioned previously we can compute the capacities corresponding to the ones given at different speeds but at some predecided speed. We shall thus obtain a large number of points all at the same speed but at different efficiencies. A smooth curve drawn through these points will be the true characteristic of this pump. The b.hp.-capacity curve of the pump can be obtained as before.

While the second method is only an approximation and the accuracy of the third depends upon the care with which the lines are drawn and the computations made, nevertheless an accuracy of 5 per cent is not unusual in the use of this method. In concluding this article the author wishes to make acknowledgment to the Wheeler Condenser and Engineering Co., from whose catalog a portion of this article was taken.

Power Plant Building Costs

Modern Design Has Brought About Changes in Building Item Costs. By John D. Morgan

IN MOST CASES power plant building costs are not comparative to other building construction costs. In the small industrial plant this does not necessarily hold true but in the larger plants and in central stations the costs are high due mainly to the fact that most large power plant buildings are located near a source of water and this entails a great amount of cofferdam work and extensive piling in order to take care of the weight of the building.

The main items of the power plant building embrace the typical building items, the subdivisions of which are given in many engineering handbooks. There is, however, a dearth of data in relation to the percentage cost distribution of these items in terms of dollars per kilowatt and boiler horsepower.

With the idea of showing the cost per cubic foot of power plant buildings, as compared to building costs, Table I was prepared. In this table, column A is the total cost of power plant building less the cost of docks, outbuildings, lawns, fences, sidewalks, bulkheads and retaining wall.

Column B is the same as column A except the cost of stacks, machine foundations, coal trestle and standard gage tracking have been omitted. Column C shows the cubical

TABLE I. POWER PLANT BUILDING COSTS BASED ON CUBICAL CONTENTS

Station	Capacity Kw.	Capacity B.hp	Type of Station	A dollars	B dollars	C cu.ft.	D cu.ft.	E cu.ft.	A/E	B/C
1	8,900	6,750	Eng.&Turb.	427,991	404,727	1,842,648	98,695	1,941,343	0.221	0.218
2	18,500	3,600	Turbine	472,034	414,627	1,465,179	114,518	1,579,697	0.298	0.283
3	10,000	4,800	Turbine	408,460	377,649	1,614,811	211,247	1,826,058	0.224	0.234
4	4,200	2,860	Eng.&Turb.	178,527	156,701	—	—	1,180,994	0.151	—
5	1,600	1,000	Eng.&Turb.	40,487	28,708	182,474	1,491	183,965	0.221	0.157
6	3,000	4,500	Turbine	115,142	91,461	621,973	6,796	628,769	0.183	0.147
7	17,900	10,050	Eng.&Turb.	673,589	519,064	2,664,064	175,251	2,839,315	0.239	0.195
8	6,450	7,700	Eng.&Turb.	352,789	303,549	1,496,864	97,378	1,594,242	0.221	0.213
9	75,000	30,120	Engine	1,312,462	1,121,378	4,590,041	662,276	5,252,317	0.249	0.244
10	9,600	5,610	Turbine	364,258	276,485	1,783,688	37,968	1,821,656	0.202	0.155
11	4,800	4,192	Engine	256,318	200,663	1,495,295	12,273	1,507,568	0.169	0.134

TABLE II. COMPARATIVE COSTS OF VARIOUS SIZED POWER PLANTS AND BUILDINGS

Station	Capacity Kw.	Capacity B.Hp.	Type of Station	No. of main generating units	Total station cost dollars	Total building cost dollars	Building Cost % total station cost	Building Cost per Kw. $	Building Cost per B.Hp. $	Building Cost per one main unit $
1	675	792	Eng.	3	184,685	32,208	17.5	47.50	40.60	10,736
2	800	750	Eng.Non-cond.	2	93,890	23,490	25.1	29.40	31.30	11,745
3	1,280	620	Eng.	5	282,750	81,405	28.8	63.60	131.20	16,281
*4	3,525	3,450	Eng.	4	929,110	350,133	37.7	99.40	101.40	87,533
5	4,800	4,192	Eng.	6	1,351,746	270,861	20.0	56.40	64.90	45,144
6	6,450	7,700	Eng.	8	2,013,219	385,995	19.2	59.80	50.10	48,749
7	2,140	2,472	Eng. & Tur.	5	479,982	93,119	19.5	43.50	37.70	18,624
8	3,000	4,500	Eng. & Tur.	4	658,584	158,832	24.2	52.90	35.30	39,708
9	4,200	2,860	Eng. & Tur.	7	924,132	214,703	23.3	51.10	74.90	30,672
10	5,950	3,371	Eng. & Tur.	5	637,432	125,618	19.7	21.10	37.30	25,144
11	8,900	6,750	Eng. & Tur.	7	1,637,079	490,578	29.9	55.10	72.75	70,083
12	9,600	5,610	Eng. & Tur.	13	1,849,709	424,416	23.0	44.20	75.40	32,647
13	17,900	10,050	Eng. & Tur.	12	2,807,504	760,998	27.1	42.50	76.10	63,416
14	1,600	1,000	Tur.	3	199,542	54,320	27.3	33.90	54.30	18,107
*15	10,000	4,800	Tur.	2	1,280,144	473,381	37.0	47.30	98.40	236,691
16	18,500	3,600	Tur.	3	1,475,114	513,579	34.8	27.70	142.60	171,193
17	75,000	30,120	Tur.	8	6,449,500	1,569,774	24.3	20.90	52.00	196,222
*18	50,000	5,492	Tur.	2	3,949,845	1,503,115	38.2	30.10	274.00	751,558

* Building can care for additional units.

contents, in cubic feet, in the building from the basement floor or concrete mat to and including the roof and monitor.

Column D gives the number of cubic feet in the mat or foundation of the building below the basement floor. Column E equals columns C plus D or the total cubic feet within the building from and including the foundation mat to the roof and monitor.

TABLE III. DETAILED PERCENTAGE COST OF A 50,000 KV.A. POWER PLANT BUILDING

Item	Per cent of Total Bldg. Cost
Foundation and piling—	
Excavating and coffer dam	2.05
Piling work, 8400 piles	7.50
Concrete, 12,985 cu. yd.	12.95
Ash filling, 8424 cu. yd.	0.94
Main building, steel. Bunkers 800 T., Boiler house 1400 T., Turbine room 750 T., Switch house 500 T., Steel stacks 384 T.—Total 3824 T.	25.60
Structural steel for coal tower and skiphoist foundations	5.28
Dock	14.55
Building items—	
Concrete mass	0.04
Concrete floors	5.01
Common brick	7.43
Face brick	0.37
Enamel brick	0.16
Kalomein doors	0.84
Wood doors	0.12
Steel roll doors	0.25
Sash	2.97
Skylight	0.68
Sash operators	0.60
Terra cotta and plaster	0.51
Iron and steel	1.08
Sheathing temporary end	0.50
Sheathing asbestos	0.29
Linoleum floors	0.08
Terrazol floors	0.03
Clocks	0.12
Terra cotta	0.18
Painting	0.89
Plumbing	1.42
Miscellaneous	1.16
Lime stone	3.05
Copper work	1.98
Roof covering	1.19

In the next to the last column of Table I are shown the items A ÷ E, this being the cost in dollars per cubic foot of space enclosed within the building. This is based upon the total contents of the building and its total cost. The last column shows the items B ÷ C, or the cost in dollars per cubic foot of building content based upon the cost of building, less stacks, machinery foundations, coal trestle and trackage; and the cubical contents of the building above the basement floor.

Table II shows for 18 various sized plants, the rating in kilowatts and boiler horsepower; the type and number of prime movers used; total cost of the station; total building cost; building cost as a per cent of total station cost; building cost per kilowatt and per boiler horsepower and the building cost per one main unit. Table III shows the itemized detail percentage cost of the various items entering into the building costs of a 50,000 kv.a.

All costs shown in these tables are based on 1924 costs, the actual costs having been brought up to date.

Great changes have taken place in the power station building design of late years. Not so many years ago, the steel cost was small, now it is generally at least 20 to 30 per cent of the total building cost. The price of steel per 1000 cu. ft. of buildings for seven large and new modern power plants ranged from $0.625 to $0.84, the average being $0.705.

Magnetic Recovery of Combustible in Boiler Plant Refuse

By Rudolf Kudlich*

THE realization that fuel costs, high as compared with those enjoyed prior to the war, are apparently permanent, has caused steam power plant operators to apply their best efforts towards improving the fuel economy of their plants. Though they have given much attention to the reduction in combustion losses by improving methods of firing and improved equipment, and to diminishing the heat losses by more care in maintaining clean heating surfaces and tight and adequate baffling, they have almost universally neglected the waste that occurs from discarding unconsumed combustible with the boiler refuse.

Though in America we have paid little attention to the recovery of fuel from refuse, in Europe considerable experimenting has resulted in the development of several types of machines for reclaiming combustible matter from boiler or furnace refuse. While the operation of most of these machines is by wet separation, either by floatation or by jigging, one machine operating on the magnetic principle has proved satisfactory, and judging by notices appearing from time to time in the technical press, quite a number of installations have been made.

These magnetic separators are based on the discovery that when coal is subjected to heat the ash forming constituents tend to fuse together into clinkers quite separate from the unburned coal and coke. The iron which is present in the impurities of practically all coals, segregates with the other ash forming constituents to form a weakly magnetic clinker, while the combustible is non-magnetic. By passing the boiler refuse, crushed to such a size that the mechanical bond between the clinker and combustible is broken, over a magnetic field the clinker is retained by the magnet while the combustible passes on.

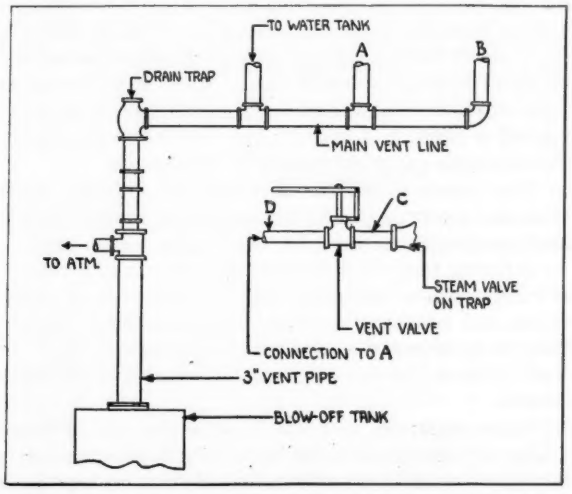
By this method a more or less complete separation of the ash from the combustible is possible, depending on the amount of iron present. Tests reported by a German firm using a magnetic drum type separator showed recoveries up to 87 per cent of the combustible in the refuse. An American firm in making tests of magnetic recovery of combustible were able to recover approximately 50 per cent of the combustible with a standard magnetic separator when crushing the refuse to ¾ in. and smaller. A special separator with characteristics adapted to the material treated would probably give a greatly increased recovery.

*Assistant to chief mechanical engineer, Bureau of Mines.

Trap Troubles

IT IS the unexpected that causes us the most trouble at times, as the following will show. One of my boiler feed traps had failed for some time to furnish sufficient water to the boilers especially when there was a heavy load and it became necessary to start another trap to help out.

This trap had always furnished plenty of water regardless of the loads. After looking for the trouble for some time, I finally discovered that the vent valve was nearly clogged up with scale such as accumulates in the boilers. The puzzling part of it was, where had this scale come from? I never had this trouble during all the years I have used traps.



ARRANGEMENT OF BLOWOFF PIPING THAT PERMITTED SCALE TO ACCUMULATE IN THE TRAP VENT

At first I was under the impression that at some time one of the boilers had foamed badly and some of this dirty water had found its way into the trap tank through the steam pipe and eventually into the vent valve and pipe connections; however, on disconnecting the pipe and valve, I found that this had not been the trouble as the nipple, c, shown in the accompanying sketch, between the trap's steam valve and vent valve was clear of scale, but the vent valve and pipe D were nearly clogged up.

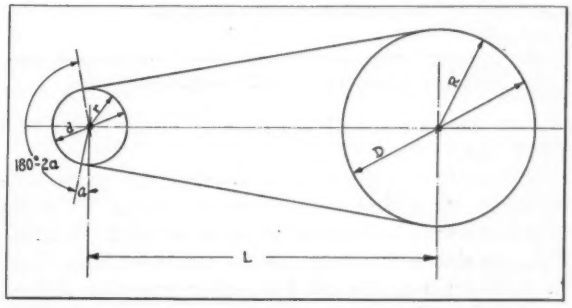
In thinking the matter over, I came to the conclusion that the trouble was caused in the following way. The dirty water from the boilers is discharged into a blowoff tank as shown. The vent pipe is arranged as shown. Some time ago I connected the vent pipes from the traps into one main pipe as shown at A. B. then ran this main pipe into the hot water tanks and, to drain the condensation from this main pipe, and not waste steam, I placed a ¾-in. radiator trap at the end of this pipe. The outlet from this was connected into the vent pipe of the blowoff tank. Some of the dirty water is blown out of the boilers mornings and noons. Should the blowoff valves be opened a little too wide and build up pressure in the blowoff tank, the dirty water would back up into the vent pipe through the trap and into the main vent pipe of the traps.

The trouble was remedied by placing a ¾-in. swing check valve between trap and blowoff tank vent pipe.

Milwaukee, Wis. H. A. JAHNKE.

Handy Arc of Contact Rule

HERE IS a handy kink for the belt man that gives sufficiently accurate results for most drives for determining the angle of belt contact on the small pulley. Belt contact on the small pulley is usually most important, because there is always less belt wrap on the small pulley than on the large unless an idler is used.



ANGLE OF CONTACT IS $180 - [58(D-d) \div L]$

Referring to the accompanying sketch, R is the radius of large pulley, r the radius of small pulley, L the distance between centers of shafts and sin a = (R—r) ÷ L.

From trigonometric tables we find

Sin 1 deg. = 0.017,452
Sin 10 deg. = 0.173,648
Sin 20 deg. = 0.342,02
Sin 30 deg. = 0.500,00

Dividing the number of degrees by its sine we find that ranging from 1 to 30 deg. the quotients are nearly constant, varying only from 57.5 to 60, with an average of 58.

1 ÷ 0.174,52 = 57.5
10 ÷ 0.173,648 = 57.7
20 ÷ 0.342,02 = 58.2
30 ÷ 0.500,00 = 60.0
Average 58

This means, in the case of belted pulleys with the arc of belt contact varying from 180 to 120 deg., that there is not much change in the intermediate sines. Hence the following formula will give sufficiently accurate results for

any ordinary belt drive up to the point where the angle equals 30 deg. Even beyond 30 deg. it will not be far wrong, because where a is as much as 45 deg. we would have the quotient 63.7 instead of 58; however, it seldom happens, these days, that an arc of contact as small as 120 deg. is allowed.

In view of this fact, we may substitute a ÷ 58 for sin a in the equation, hence

$$(R—r) \div L = a \div 58$$

and therefore $a = 58\ (R—r) \div L$.

But the angle of belt contact is

$$180 — 2a = 180 — [58 \times 2\ (R—r) \div L]$$

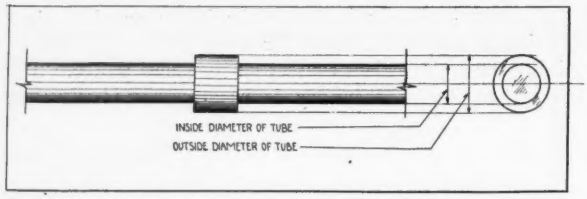
Since pulley diameters are usually given rather than radii we can convert this into the most convenient form.

$$\text{Degrees of contact} = 180 — [58\ (D—d) \div L]$$

Newark, N. J. W. F. SCHAPHORST.

Removing Split Condenser Tubes

I HAVE recently devised a method, which may be of interest to operating engineers, whereby I have been able to remove a split condenser tube and insert a new one in a double water-box type condenser, without losing more than



TOOL FOR REMOVING SPLIT CONDENSER TUBES

2 in. of vacuum and with the turbine pulling 75 per cent of full load.

We have a steel pin made as shown in the accompanying sketch, about 8 in. long with a shoulder at the center equal to the outside diameter of condenser tube. Each end of the pin should fit snugly into the condenser tube. Place one end of pin in the old tube, after removing packing ferrules, then place the new tube on the other end of pin and push the new tube through. The old tube will be pushed out the other side of condenser. Pack the new tube and the job is done. We have had to replace quite a number of tubes and have never had to shut down to put in new ones. C. C.

Irregular Boiler Feeding

COMMENTING ON John D. Morgan's article, "Irregular Boiler Feeding Lowers Efficiency" in the July 1 issue, I would say that while it is conceivable that conditions might exist where the boilers would repeatedly be filled up with cold water to such an extent as to require blowing down to prevent slugs of water passing over into the steam line, losses of from 3 to 10 per cent would be abnormal. When a discussion is presented of savings to be made by installation of certain apparatus or methods of operation the only reasonable basis of comparison is average practice under the former conditions, and unless this is done it is valueless and misleading. Where does the 3 to 10 per cent go?

Feed pump pressure regulators are valuable both in saving the feed piping from undue pressure and in making it easier for the fireman to adjust the feed without continuous trips to the pump throttle but a centrifugal pump of the proper number of stages and runner characteristics so as not to give excessive pressures at low rates of flow will greatly reduce feed line trouble and packing consumption even over a well-maintained duplex pump. Unfortunately these are not well adapted for small boilers but above 500 to 1000 boiler horsepower are well worth the extra cost.

Fortunately the average water tender is by no means as helpless as Mr. Morgan would lead one to believe; it requires comparatively little practice to form a fair idea of the relative capacity being developed from judging the speed of the pump and he can also give a good estimate of what the individual boilers are doing by the number of turns open of the feed valves. An inexpensive convenience is a feed line pressure gage located where the fireman can easily see it and tell how the pump is functioning without visiting the pump room. A single feed water recording meter, located conveniently near the pump is a convenience in encouraging uniform feeding but any operating man can picture what the boss would say if he blew a fusible plug or burned a sheet and offered as an excuse that the water meter was reading the same as the steam meter and he didn't look at the water gage. Much of the metering apparatus will be most desirable and effective when it has reached a stage of simplicity and reliability comparable with Bourdon gages and electrical instruments.

The curves shown for superheat at different water levels and presumably different ratings are interesting, but more explanation is needed to show what reason there is for believing that the differences are not due to variations in rate of steam flow other than to the action of superheater and whether the points represent single observations or averages of a number of readings so that one could be sure that the phenomenon repeated itself indefinitely.

Large variations in water level between the different drums of longitudinal drum water-tube boilers are due to improper equalizing connections and if these are kept clear, as they should be in any well-run boiler plant, little difficulty will be encountered. In cross drum boilers of the Stirling and similar types considerable difference in level was expected, due to the circulation and provision made that when the water level showed right on the glass the steam nozzle would be well clear of the water level and priming.

New Haven, Conn. H. D. FISHER.

Feeding Soda Ash

IN REGARD to the letter on feeding soda ash, by H. A. Jahnke on page 968 of the September 15 issue, I believe it a mistake to use a large plug in the makeup of a feeder, such as shown on Mr. Jahnke's feeder in Fig. 2. This plug must be unscrewed every time the feeder is charged with the soda ash compound. Considerable force must be used to make a 2-in. plug liquid tight against a boiler pressure even as low as 125 lb. It would be better to use a ¾-in. nipple with a valve and funnel for filling, a bushing being used instead of the 2-in. plug. Should the ¾-in. valve develop a leak after a time, it is only a few minutes' work to put on a new disc.

By using a pipe cap on each end of the 5-in. chamber, with holes drilled and threaded to take the small pipes and by using a ¾-in. valve instead of the 2-in. gate valve

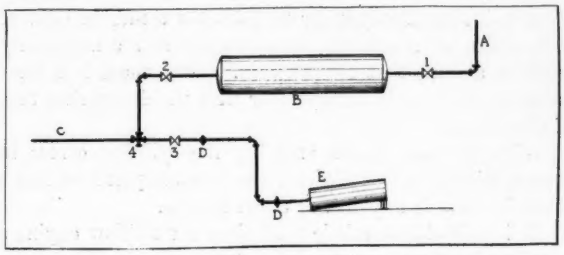
shown, the appearance of the feeder will be improved. There will be less difficulty in making it liquid tight, as the number of large diameter threaded joints is reduced. In addition the cost of making the feeder is considerably lessened, because the 5-in. bushings, tee and coupling, and the 2-in. plug nipple, valve and bushing are all dispensed with, and replaced with the prepared caps, ¾-in. nipple, valve, and funnel.

Toronto, Can. JAMES E. NOBLE.

Charging Ammonia System

I HAVE READ several articles in late issues of Power Plant Engineering on the subject of charging ammonia systems, all of which describe methods which differ in some respects from the one I use.

Referring to the accompanying sketch; A is the liquid line from the condenser to the receiver, B; C is the liquid line from the receiver to the expansion coils; D and D are flanged unions; G is the line connecting the ammonia



PIPING ARRANGEMENT FOR CHARGING AMMONIA SYSTEM

drum, E, with the line C. Valves 1, 2 and 3 are stop valves and 4 is a three-way valve.

When ammonia is needed line G is connected up with drum E, slightly inclined to let the liquid flow from drum. Open valve 3 slightly and in a few moments, if there are no leaks, open it wide. Next close the three-way valve 4 and open the stop cock on the ammonia drum. When the drum is empty the expansion pressure will begin to drop, line G will get cold and usually frost over. When the drum is empty valve 3 is closed, valve 4 opened, the stop cock on the ammonia drum closed and the drum disconnected from the line. In the Sept. 1 issue, page 915, A. K. Vradenburgh recommends pumping down to a slight vacuum before disconnecting the drum. I believe this is unnecessary and there is danger of getting air in the system when it is pumped down to and below atmospheric pressure. There is only about 1 lb. loss on a 150-lb. drum when disconnecting at 15 lb. gage. He also states that the suction pressures should be carried at 25 to 35 lb. I believe there are few refrigerating and ice making systems that can successfully carry a suction pressure as high as 35 lb. gage, as the boiling point or saturation temperature of ammonia at 34.3 lb. gage is 20.37 deg. F.

San Angelo, Texas. G. U. SWANN.

Keeping the House Clean

WHILE THERE is undoubtedly a lot of truth on the editorial, "Keeping the House Clean" which appeared on page 922 of the Sept. 1 issue, it seems to place undue blame on the operating or chief engineer for a dirty power plant.

We shall occasionally find plants where the man in charge will do his best to bring things to a state of perfection but he must have the sanction of the big boss who frequently can see it only from the financial point of view.

Cleaning house is like buying equipment that will show a good return. Sometimes the boss can't see anything but the first cost.

A dirty plant is not always caused by inefficient operation; on the other hand, it is frequently caused by acute tightwaditis on the part of the man behind the cash pile.

Old Forge, N. Y. R. G. SUMMERS.

Old Two-Valve Engine Still Operates

THE TWISS Automatic Engine shown in Fig. 1 was built by the R. Hill Machine Co. in Holyoke, Mass., about 40 yr. ago. According to reports, few of these engines

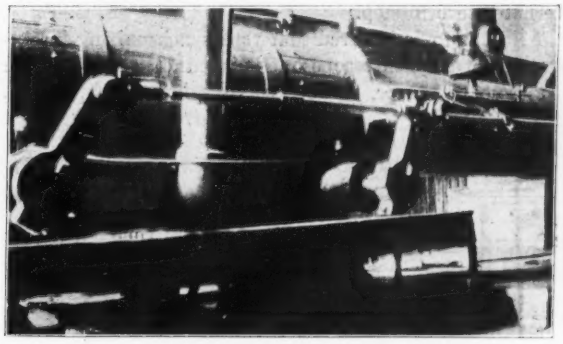


FIG. 1. TWISS TWO-VALVE ENGINE, 40-YR. OLD

were ever built. I have located three in Holyoke, all of which are still operating, two driving paper machines and the other a small d. c. generator.

From the name we should expect the engine to be governed by an automatic cutoff. This may have been the original design, although all are now equipped with fixed eccentrics and throttling governors.

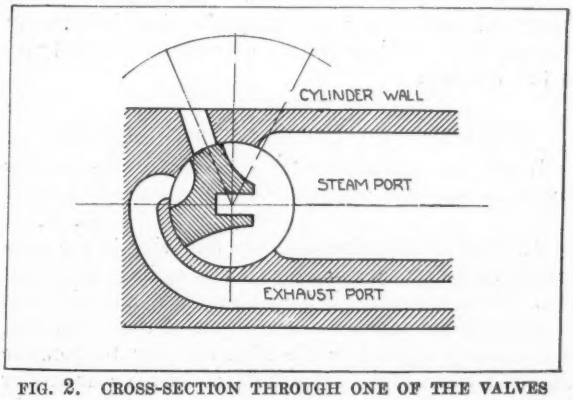
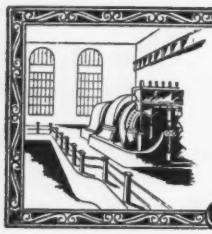


FIG. 2. CROSS-SECTION THROUGH ONE OF THE VALVES

As shown in the sketch, the valve is of the Corliss type with two ports, one for steam and the other for exhaust. One is located at each end of the cylinder. It can be seen from the sketch that the eccentric must follow the crank. The eccentric rod transmits its motion to a direct rocker, which is connected to the crank end valve by a carrier rod. A link connects the two valve cranks.

The engine shown in the photograph has a 12 by 30-in. cylinder and carries a load of 50 hp. at 74 r.p.m.

Holyoke, Mass. C. W. WALTON, JR.

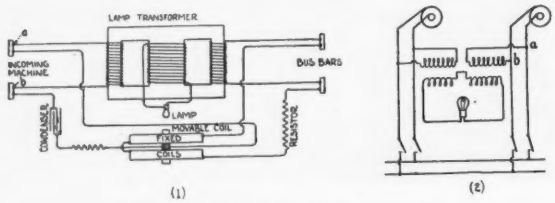


QUESTIONS AND ANSWERS

Synchronizing Lamp Connections

I WOULD like to know what changes are necessary in the connections of a synchroscope when it is dark at synchronism and the lamps are light. It is desired that that synchroscope be light and the lamps dark when the alternators are in step. F. C. E.

A. It is to be inferred that your synchronizing instrument is not a synchroscope but it is rather what is known as a synchronoscope. The accompanying sketch, No. 1, shows the wiring diagram of this instrument.



SYNCHRONOSCOPE CONNECTIONS

According to the hook-up shown, the synchronoscope lamp is dark at synchronism. To rearrange the wiring in order to have the light at full brilliancy at synchronism, it will simply be necessary to interchange the two connections marked "A" and "B." Sketch No. 2 is a standard arrangement for hooking with synchronizer lamps. If the present hook-up is such that the lamp is at full brilliancy when the alternators are in step, then to rearrange the wiring to have the lamp dark at synchronism, it is simply necessary to interchange the two connections "A" and "B" on this diagram.

Principle of the Uniflow Engine

WHAT ARE the advantages claimed for the uniflow engine as compared with the common counter-flow type? H. H.

A. One of the principal losses occurring in the ordinary counter-flow engine is that due to cylinder condensation. Steam expanding in a cylinder suffers a considerable reduction in temperature and any part of the engine that is alternately exposed to the high and low temperature assumes a mean of the two extremes. In the counter-flow engine, then, where the high pressure steam enters and the exhaust leaves the same end of the cylinder, the cylinder walls and heads have a temperature lower than that of the incoming steam, hence there is considerable condensation during the first half of the stroke.

During the latter portion of the stroke the cylinder walls are at a higher temperature than the steam and for this reason some re-evaporation takes place. This of course causes a tendency toward a rise in steam pressure but the effect is not great and is insufficient to compensate for the loss occurring during the first part of the stroke.

In the uniflow engine, high pressure steam enters at one end of the cylinder and exhaust takes place at the end of the expansion stroke through ports located at the middle of the cylinder. The cylinder is about twice as long as the stroke and the thickness of the piston is about equal to the stroke so that at the end of, say, the head end stroke the head end face of the piston uncovers the ports at the center of the cylinder.

With this arrangement the steam passes directly through the cylinder from one end to the middle and any given point on the cylinder wall always comes in contact with steam at a constant temperature and consequently tends to assume that temperature. Thus there is a temperature gradient in the cylinder wall which matches that of the steam.

High pressure steam entering the cylinder comes in contact with a surface of about the same temperature, hence there is little if any initial condensation.

It is this characteristic that gives the uniflow engine a certain advantage over the other type.

What Causes Vacuum Pump to Take Water

IN THE plant where I am employed we have a 22 by 42 by 48-in. cross compound Corliss engine which is served by a barometric condenser. On several occasions lately we have had emergency shut-downs, due to the fact that the vacuum pump would take a full stroke of water in through the vacuum pipe. When this occurs the vacuum pump will race and then slow down, causing the vacuum to fluctuate widely, and end by losing the vacuum altogether.

What causes this condition and how can it be remedied?

Apparently the pump is in perfect operating condition. The water line to the condenser is a 7-in. pipe and the valve on this line is open three turns. The vacuum line, from the top of the vacuum chamber, is 3 in. O. W. H.

Determination of Stress in Coal Bunker Supports

WITHOUT THE use of calculus, determinents or simultaneous equations, how may the reaction at the four corner supports of the coal bunker shown in the accompanying sketch be determined? Dimensions are shown on the sketch and the bin is to hold pulverized coal. J. M.

A. To solve this problem, it is first necessary to find the volume of the bunker, the total weight to be supported and the center of gravity of the mass. Knowing these values, the corner reactions, A, B, C and D may be found by solving a series of moment equations.

Obviously the volume of the rectangular figure representing the upper portion of the bin is

$$V_1 = 15 \times 10 \times 5 - 750 \text{ cu. ft.},$$

and the volume of the lower portion, the pyramid, neglect-

ing that small part of the apex cut off by the opening at the bottom, is

$$V_2 = \text{area of the base} \times \tfrac{1}{3} \text{ the altitude}$$
$$= 15 \times 10 \times 12 \div 3 = 600 \text{ cu. ft.}$$

As the bin is to contain pulverized coal, which weighs about 35 lb. per cu. ft., the weight of the upper section will be

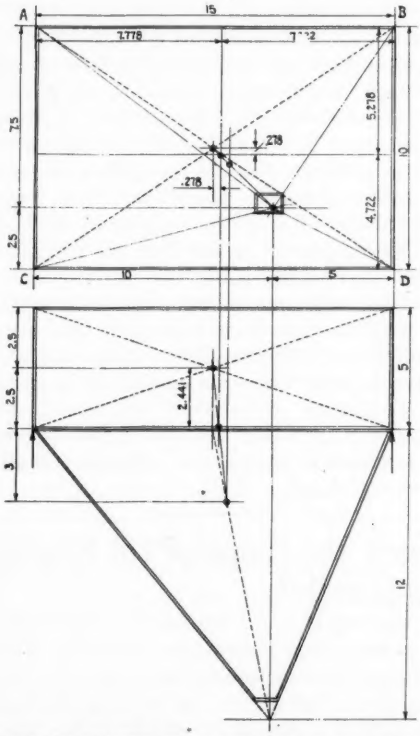
$$W_1 = 35 \times 750 = 26{,}250 \text{ lb.}$$

and the weight of the lower section will be

$$W_2 = 35 \times 600 = 21{,}000 \text{ lb.}$$

The total weight, W, is therefore 47,250 lb.

For the purpose of the problem, the weight of the bin itself may be neglected; practically it should be taken into consideration.



IRREGULAR SHAPED COAL BUNKER IS TO BE SUPPORTED ON COLUMNS AT THE FOUR CORNERS

The center of gravity of the upper section lies at the intersection of the diagonals. As shown in the sketch, it is, in the plan view, 7.5 ft. from the ends, 5 ft. from sides and, in the elevation, 2.5 ft. down from the top. The center of gravity of the pyramid lies on a line connecting the intersection of the diagonals of the base with the apex and is ¼ the altitude or 3 ft., distant from the base. In the elevation it will be seen by considering similar triangles that it lies $2.5 \times 9 \div 12 = 1.875$ ft. from a vertical plane perpendicular to the paper, passing through the apex.

Referring to the vertical elevation again, the resultant center of gravity lies on a line connecting the two previously found. Its position may be found by taking moments about a horizontal axis through that, as yet unknown point. If X is the vertical distance of the upper and y that of the lower center from the resultant center then

$$26{,}250\ X = 21{,}000\ y$$

The sum of X and y is of course equal to the total vertical distance beween the two centers,

$$X + y = 3 + 2.5 = 5.5 \text{ ft.}$$

and therefore $y = 5.5 - X$.

Substituting this value for y in the first equation

$$26{,}250\ X = 21{,}000\ X\ 5.5 - 21{,}000\ X$$

therefore, $X = 2.441$ ft.

Carrying this point back to the plan view, it will be found that the resultant center of gravity is 0.278 ft. below and 0.278 ft. to the right of the center of gravity of the upper section of the bin. Its location with respect to the sides is indicated on the sketch.

To find the corner reactions A, B, C and D, it is first necessary to find resultant reactions A + C and B + D at the intersection of the axis through the center of gravity with the sides A-C and B-D respectively.

Taking moments about the side B-D,

$$15\ (A + C) = 7.222\ W$$

hence $A + C = 7.222\ W \div 15 = 0.481\ W.$

In like manner by taking moments about the side A-C,

$$15\ (B + C) = 7.778\ W$$

hence $B + C = 7.778\ W \div 15 = 0.519\ W.$

To find the reaction at A, take moments about C,

thus $10\ A = 4.722 \times 0.481\ W$

hence $A = 0.227\ W.$

Since $A + C = 0.481\ W$

$$C = 0.481\ W - 0.227\ W = 0.254\ W$$

Similarly, taking moments about D,

$$10\ B = 4.722 \times 0.519\ W,$$

hence $B = 0.245\ W$

and $D = 0.519\ W - 0.245\ W = 0.274\ W.$

Since the weight, W, is 47,250 lb., the corner reactions will be

$$A = 0.227 \times 47{,}250 = 10{,}725 \text{ lb.}$$
$$B = 0.245 \times 47{,}250 = 11{,}575 \text{ lb.}$$
$$C = 0.254 \times 47{,}250 = 12{,}000 \text{ lb.}$$
$$D = 0.274 \times 47{,}250 = 12{,}950 \text{ lb.}$$
$$47{,}250 \text{ lb.}$$

Ten Degrees Increase in Feed Temperature Saves One Per Cent

How much coal is to be saved in raising the feed water temperature 10 deg. say from 180 to 190 deg. F.? We now use about 50,000 gal. in 24 hr. We use a good grade of bituminous coal of about 13,000 B.t.u. per lb. under horizontal return tubular boilers which are in good condition.

W. H. B.

A. Not enough data is given to answer this question exactly but by making a few assumptions it is possible to outline the method of solution. For an actual problem, actual values may be substituted.

If it is assumed that the boiler delivers dry saturated steam at a pressure of 100 lb. abs., then the total heat of the steam, as found from a steam table, is 1186.3 B.t.u. per lb. and the heat added per pound evaporated is $1186.3 - 180 + 32 = 1038.3$ B.t.u. If the feed water temperature is raised 10 deg. then for every pound evaporated the furnace will be required to supply 10 B.t.u. less or 1028.3 B.t.u. and the saving will amount to $10 \div 1038.3 = 0.96$ per cent.

If, under the present conditions, the actual evaporation is 7 lb. per pound of coal fired then for every pound of water evaporated the saving will be $0.00961 \div 7 = 0.00137$ lb. of coal. During a day's run this will amount to $0.00137 \times 8.33 \times 50{,}000 = 520$ lb. or about ¼ T.

EDITORIAL COMMENT

Citizenship—Your Job

In these United States of America, of what does citizenship consist? In a democracy, every voter is a partner in the government. He is entitled to his share in the benefits of operation of the concern but he is given a certain responsibility for its success. He is responsible for obeying the laws, for paying his share of the expense of operation, for avoiding infringement of his neighbor's rights. But he is also responsible for the election of a president and other officers of the partnership who will manage its affairs wisely. Here is where more than 50 per cent of the citizens fall down.

Being a free American, of course you kick when laws are passed that you don't like and when taxes are too high and when government officials betray their trust. But what do you DO about it? If you have registered and voted at every election, this is not for you—except that you can make sure that your shopmate and your neighbor and your fellow lodge member and their wives and your wife do likewise in the coming election. If you have been neglecting this fundamental responsibility of partnership in your government, now is the time to reform.

It is especially important that this election be a real expression of the will of a majority of ALL the voters of the country. That cannot be the case if half or more of the voters stay away from the polls as was the case in the last presidential election. Power Plant Engineering has no desire to influence your vote for any party or any candidate. It *is* concerned that you express your judgment as to the candidates who will be best qualified to administer the government in the country, in your state, in your city, in the only way which is effective. To register and cast your ballot is a fundamental responsibility of citizenship. To use every effort to have the other fellow do it is to ensure that he "totes fair" in the government partnership.

Age of Steam and Electricity

References are often made to the age of steam which had its true beginning with the invention of the steam engine and its application to the factory and modes of travel on both land and sea. Of late, much is said and written of the age of electricity, this having been brought about by the spectacular advancement of the application of this form of energy, not only to transportation and the production of commodities of daily consumption but also to its common-place use within our homes.

Notwithstanding this development and the tendency to refer to this as the age of electricity, the fact should not be forgotten that this is in truth the age of steam and electricity, for as advancement has been made in the use and application of electricity, so has there been a corresponding advancement made in the generation and use of steam. Further, it should not be forgotten that steam is as yet the fundamental source of power by means of which the production of electricity is made possible.

With this in mind it is readily understandable that, from an economic point of view, steam and electricity cannot be separated. This is not a temporary condition because the demand for power and electricity is increasing at an enormous rate and it has been estimated that, if all our available water power were in use, it would fail to meet our present demand. In the future, therefore, we must depend more and more upon the generation of steam as the fundamental basis for the production of power.

That steam and electricity are so closely allied is evidenced by the work which is being done by the Association of Iron and Steel Electrical Engineers. This association has found that its problems are not alone those of the use and application of electric power but that they must also be deeply concerned with the economical production of steam. The recognition of this fact has resulted in this association contributing much valuable material on the subjects of fuel consumption and steam generation.

That which is true of the association must necessarily be true of the individual. Advancement will not necessarily come to those who have specialized in the production of either steam or electricity but in all probability the favored executive and managerial positions will rest upon those who have grasped the importance of all phases of the power problem.

Widening the Scope of Oil Engine Applications

In attempting to widen the field of application for the oil engine as a prime mover for stationary plants, the manufacturers of such equipment have had to contend with a number of problems. One of these difficulties has been the high first cost of oil engine units. The second problem has been to overcome the early prejudices formed by operators who had difficulties in the operation of this type of equipment due to a lack of appreciation of the special requirements of oil engine operation and maintenance. The third drawback, in widening the field of application, has been due to the fact that engines of a size suitable for application in the larger stationary power plants, were not available.

During the past few years, however, these various problems have either been solved or their ultimate solution is reasonably assured. High costs have been cut by simplified designs and production on a quantity basis. Operating difficulties have been reduced by definite educational campaign to show the value of systematic inspection and maintenance schemes. The third handicap, lack of high ratings, appears also to be solved by the designers.

Several of the American designers of Diesel engines have been working on the last problem; that of building larger sizes. The trend of this development has been toward the use of large cylinders, two-cycle types, and two-cycle double-acting types. The last method mentioned is quite new to American practice; in fact, such an engine

was described in the "News and Development" section of the September 15 issue.

With all of the activity in the oil engine field it is apparent that the scope of application will be extended and it is quite possible that the use of such prime movers in large power plants will be practical.

Progress

If past performance is any indication of future progress it may be interesting to note what our efforts in the past have accomplished.

Prior to 1850 the United States was dominantly an agricultural country. During the 70 yr. period from 1850 to 1920 while the population increased 360 per cent, agricultural production increased 520 per cent, manufacturing increased 28 times and mining over 77 times. This enormous increase in production would indicate that the population of the United States is, from an economic point of view, considerably better off now than it was two, three or four generations ago.

Within the borders of the United States there is 40 per cent of all the installed water power in the world; 35 per cent of the railroad mileage and 57 per cent of all the telephone and telegraph lines. This country produces about 41 per cent of the world's cereals, 71 per cent of its cotton, 50 per cent of its coal, 64 per cent of its petroleum and 52 per cent of its timber. To the world's output the United States contributes 60 per cent of zinc, 48 per cent of the lead, 59 per cent of the copper and 52 per cent of the pig iron.

Economic progress is not, however, indicated by increased production alone. The factor of consumption must be taken into consideration. If consumption keeps pace with production there may be a betterment in the standard of living but economically we are no better off. It is only when the rate of increase of production exceeds the rate of increase of consumption that economic progress results. This is what has taken place in the country in the past.

If one is to become economically independent he must live within his means; he must spend less than his income if he is to build up a reserve and the same thing applies to nations as to individuals. If a man wants to attain a higher standard of living, there is only one right way to do so; he must produce more.

Off Duty

A few days ago in Washington there was held a meeting in honor of an illustrious general who was retiring from a lifetime of active service in the Army. This man has always occupied a loving place in the hearts of the American people for he, more than anybody else, typified their conception of an ideal soldier. It was fitting therefore that upon the eve of his retirement the nation should honor this peerless leader with a celebration of unusual interest.

On the evening of Sept. 12, General Pershing addressed directly a small audience in the building of the War Department in Washington. However important, this small audience was merely incidental for on the outside, he had an audience such as no other man in this world ever had before. His radio voice must have reached at least ten millions of people!

Imagine it! Ten millions of people. From the desolate storm swept coast of Labrador, to the flower-scented gardens of San Diego, every word, each tiny inflection—the very breathing in fact of this man speaking calmly in Washington was distinctly audible. The twenty stations extending from Washington to San Francisco which broadcast the proceedings did their work well and the radio listeners in California probably heard the General's voice more clearly than did those in the back rows of the room in the building of the War Department at Washington.

In this amazing manner the youngest member of the communication family serves us. Five years ago, so far as the laity was concerned radio was unknown. Today we listen calmly to a concert at a distance of two thousand miles and then dare to criticize the quality of reproduction! Indeed, when we have difficulty in tuning in a 500-watt station a thousand miles away through a one-kilowatt local station, we are quite provoked. The novelty of radio has already worn off—we accept it as a matter of fact. We do not hesitate to criticize it.

It is true this critical attitude makes for progress and is therefore an important attribute of the human race, yet it is well sometimes before we criticize unjustly, to keep in mind the history of the things we find fault with.

Do you ever ask yourself where all our modern wonders come from? Where they originate and what forces govern their development? Do you ever stop to consider the infinite patience of the workers who search out nature's secrets and apply them to our benefit?

Achievements such as radio and the telephone are evolutionary in their growth and their beginnings often arise in fields far remote from that of their final development. No one man is responsible for their development.

Radio, for instance, had its inception in 1887 in the experimental laboratory of Hertz who found that he could produce small sparks between the ends of loops of wire when brought in the vicinity of an induction coil in action. His object was the production and detection of electric waves. He had no thought of applying the action to purposes of communication. Some years before, a scientist by the name of Maxwell—James Clerk Maxwell—had demonstrated mathematically that such things as electric waves existed. Hertz, however, was not satisfied with the mere statement and set about to find these waves and to discover how to produce them.

And so today in our research laboratories men with the same inquisitive types of minds, governed by the same spirit of research, are trying to find the how and why of countless mysteries. It is to these searchers that the world owes an incalculable debt. To their perseverance and patience we owe our modern achievements. Not to the Caesars, the Napoleons or the Bismarcks whose political and military accomplishments dominate the pages of history but to the Newtons, the Maxwells, the Pasteurs, the Hertzes and the Steinmetzes whose deathless achievements will be reflected for all time in a better world, do we owe an undying debt of gratitude. They are the real torch bearers who penetrate deep into the darkness and illuminate the way so that others may follow.

So when you listen to your radio some night and are dissatisfied with its action cheer up, and show a little of the spirit possessed by those who made radio possible. If your interest so far has limited itself to what you hear over the radio, go a step farther—find out how it works, study its marvelous action. In the knowledge of its principles you will find far more fascination than you ever did in merely listening to it.

Iron and Steel Engineers Meet at Pittsburgh

TECHNICAL PROGRAM GIVEN AND EXHIBITS SHOWN AT COMMEMORATION OF 30TH ANNIVERSARY OF USE OF ELECTRIC MOTORS IN THE IRON AND STEEL INDUSTRY

ONE THOUSAND delegates to the nineteenth annual convention of the Association of Iron and Steel Electrical Engineers officially opened the technical and executive sessions and the exhibition which were held September 15 to 19 at the Duquesne Gardens, Pittsburgh, Pa. It was particularly fitting that the convention should have been held in Pittsburgh, the greatest steel center in the world, because this year marks the thirtieth anniversary of the adoption of electric motors in the manufacture of iron and steel.

Registration started September 15, in the lobby of the Wm. Penn Hotel and that evening a dance was given in the hotel ball room. The technical program was covered in four morning sessions, the afternoons and evenings being given over to inspection trips to manufacturing plants and inspections at the exhibit hall.

This association has recognized the importance of fuel and combustion in the manufacture of iron and steel and therefore the work on these subjects is being done by a fuel-saving conference. The first of these conferences was held last spring in Pittsburgh. This proved such a success that it has been decided to make the fuel-saving conference an annual function of the association's activities.

Several papers were presented at the technical sessions which would interest engineers in charge of power plants. One of these, on combustion control was presented by E. G. Bailey of the Bailey Meter Co., Cleveland, O. This paper showed that an analysis of combustion control conditions can and should be made and that the results obtained will be in proportion to the thoroughness in which the basic steps have been separated and studied. It is not claimed that automatic control is justified in all existing plants but that there seems to be no excuse why all control necessary for the fireman to operate should not be brought to a common point with the necessary metering equipment thereby enabling him to accomplish the best results without useless physical effort.

Electric heating with special reference to central stations was the subject of a paper presented by E. D. Sibley, Metropolitan Edison Co., Reading, Pa. An interesting point brought out in this paper was the fact that the capacity of industrial heating apparatus sold during the past 5 yr. by 18 manufacturers was over 830,000 kw.

In a paper on the steel industry and the electric utilities, by Merrill Skinner of the Duquesne Light Co. and F. D. Mahoney of the West Penn Power Co. it was pointed out that the advantages of interconnection to the steel companies are: elimination of vent losses over week-ends and holidays; additional coal-burning boilers are not necessary and their cost can be diverted to the purchase of equipment which would earn greater dividends; and, finally there is the advantage resulting from the simplification of the network of interconnecting transmission lines and the problem of the right of way for these lines.

IMPORTANCE OF LIMIT DEVICES DISCUSSED

In a paper on crane hoist travel limit devices, Walter Greenwood, safety engineer, Carnegie Steel Co., stated that the failure of regulating devices for control of electrical apparatus is the chief cause for mishaps that cause impairment of equipment and machinery operated by electrical equipment. Also, it is the cause for delay of operation, loss of production and injuries to persons while engaged in handling electrically operated equipment. The list of devices that fail and produce disastrous results include automatic breakers of various kinds, switches, speed limits and travel limits.

Failure of hoist limit devices is of such frequent occurrence one cannot be surprised at the attitude of some whose perference is to rely entirely on operators to stop the hoist travel at the proper time instead of employing a limit device that is not entirely dependable.

Following a general study of hoist limits, these points are emphasized: A hoist limit device should be considered as only an auxiliary to manual control. The principal features of limits are interruption of current and the application of dynamic braking. The addition of any other feature involves care and attention that means additional maintenance cost. If they do not automatically reset, the time consumed in resetting, if the method is purposely made inconvenient, will sometimes be a serious delay, and it encourages operators to make the limit inoperative.

In too many cases the installation of a protective device is made by persons who in some particulars disregard instructions furnished by the maker of the device. This is done in some cases because the requirements are thought to be unnecessary and cost can be reduced; in other cases because they think they can see better methods, and too, in some cases perhaps they do see them.

The following officers were elected for the ensuing year: President, A. C. Cummins, Elec. Supt., Carnegie Steel Co., Duquesne, Pa.; first vice-president, George H. Schaeffer, Elec. Engr., Carpenter Steel Co., Reading Pa.; second vice-president, S. S. Wales, Elec. Engr., Carnegie Steel Co., Pittsburgh, Pa.; treasurer (re-elected), James Farrington, Elec. Supt., Wheeling Steel Corp., Steubenville, Ohio; secretary, F. W. Cramer, Asst. Elec. Engr., Bethlehem Steel Co., Johnstown, Pa.

Exhibitors at the Convention of the Association of Iron and Steel Electrical Engineers

Ackurate Rubber Co.....New York, N. Y.
Alliance Machine Co.....Alliance, O.
Allis-Chalmers Mfg. Co.....Milwaukee, Wis.
American Engineering Co.....Philadelphia, Pa.
American Steel & Wire Co.....New York, N. Y.
The Andresen Co.....Pittsburgh, Pa.
Appleton Electric Co.....Chicago, Ill.
Automatic Reclosing Circuit Breaker Co....Columbus, O.
Axwell Equipment Co.....Pittsburgh, Pa.

Bacharach Industrial Instrument Co.....Pittsburgh, Pa.
Baker, R. & L., Co.....Cleveland, O.
Bartlett-Hayward Co.....Baltimore, Md.
Earl B. Beach Co.....Pittsburgh, Pa.
Benjamin Electric Mfg. Co.....Chicago, Ill.
W. A. Bittner Co.....Pittsburgh, Pa.
Alfred Box & Co.....Pittsburgh, Pa.
Allen Bradley Co.....Milwaukee, Wis.
Bussmann Mfg. Co.....St. Louis, Mo.

The Calorizing Co.....Pittsburgh, Pa.
Carbo Oxygen Co.....Pittsburgh, Pa.
Central Electric Co.....Chicago, Ill.
Chicago Fuse & Mfg. Co.....Chicago, Ill.
Chicago Pneumatic Tool Co.....New York, N. Y.
Corliss Carbon Co.....Bradford, Pa.
Crocker-Wheeler Co.....Ampere, N. J.
Crouse-Hinds Co.....Syracuse, N. Y.
Cutler-Hammer Mfg. Co.....Milwaukee, Wis.
The Cutter Co.....Philadelphia, Pa.

The De Laval Separator Co.....New York, N. Y.
De Laval Steam Turbine Co.....Trenton, N. J.
Delta Star Electric Co.....Chicago, Ill.
M. H. Detrick Co.....Chicago, Ill.
Doubleday Hill Electric Co.....Pittsburgh, Pa.
Dravo Doyle Co.....Pittsburgh, Pa.
Duquesne Light Co.....Pittsburgh, Pa.

Eastman Graf Co.....Pittsburgh, Pa.
Economy Fuse & Mfg. Co.....Chicago, Ill.
Edison Storage Battery Co.....Orange, N. J.
Electric Controller & Mfg. Co.....Cleveland, O.
Electric Materials Co.....North East, Pa.
Electric Service Supplies Co.....Philadelphia, Pa.
Electric Storage Battery Co.....Philadelphia, Pa.
Eleveyor Industrial Truck Corp.....Brooklyn, N. Y.
The Esterline-Angus Co.....Indianapolis, Ind.

Fairbanks, Morse & Co.....New York, N. Y.
Farrell Foundry & Mach. Co., Inc.....Buffalo, N. Y.
Fuller-Lehigh Co.....Fullerton, Pa.

General Electric Co.....Schenectady, N. Y.
Griscom-Russell Co.....New York, N. Y.

The Hayward Co.....New York, N. Y.
Herr & Harris Co.....Pittsburgh, Pa.
Homestead Valve Mfg. Co.....Homestead, Pa.
Ludwig Hommel & Co.....Pittsburgh, Pa.
Howell Electric Motors Co.....Howell, Mich.
Hyatt Roller Bearing Co.....Harrison, N. J.

Ilg Electric Ventilating Co.....Chicago, Ill.
Iron City Electric Co.....Pittsburgh, Pa.

Johns-Manville Co., Inc.....New York, N. Y.
Jos. Jacques .....Pittsburgh, Pa.

H. Kleinhaus Co.....Pittsburgh, Pa.

Lakewood Engineering Co.....Cleveland, O.
J. Frank Lanning Co.....Pittsburgh, Pa.
Laughlin & Barney Machinery Co.....Pittsburgh, Pa.

Mercury Mfg. Co.....Chicago, Ill.
Midwest Air Filter, Inc.....New York, N. Y.
Moloney Electric Co.....St. Louis, Mo.
Monitor Controller Co.....Baltimore, Md.
Morgan Engineering Co.....Alliance, O.
Mutual Electric & Mach. Co.....Detroit, Mich.
Mutual Foundry & Mach. Co.....Atlanta, Ga.
W. A. McCombs Co.....Pittsburgh, Pa.
C. H. McCullough Eng. Co.....Pittsburgh, Pa.
McGraw-Hill Co.....New York, N. Y.

National Carbon Co.....Cleveland, O.
National Electric Mfg. Co.....Pittsburgh, Pa.
National Lamp Works of G. E. Co.....Cleveland, O.
New Departure Mfg. Co.....Bristol, Conn.
Nichols-Lintern Co.....Cleveland, O.
The Norma Co. of America.....Long Island City, N. Y.

Ohio Electric & Controller Co.....Cleveland, O.
The Okonite Co.....Passaic, N. J.
Otis Elevator Co.....New York, N. Y.

Packard Electric Co.....Warren, O.
Payne-Dean, Ltd.....Stamford, Conn.
Pawling-Harnischfeger Co.....Milwaukee, Wis.
Pittsburgh Electric Furnace Corp.....Pittsburgh, Pa.
Pittsburgh Electrical & Mach. Works.....Pittsburgh, Pa.
Pittsburgh Transformer Co.....Pittsburgh, Pa.
The Pyle-National Co.....Chicago, Ill.

Railway & Industrial Engineering Co.....Greensburg, Pa.
Reed Air Filter Co., Inc.....Louisville, Ky.
Reliance Electric & Engineering Co.....Cleveland, O.
Republic Flow Meters Co.....Chicago, Ill.
H. Lee Reynolds Co.....Pittsburgh, Pa.
Robbins & Myers Co.....Springfield, O.
Robinson Ventilating Co.....Pittsburgh, Pa.
Rollway Bearing Co.....Syracuse, N. Y.
Rowan Controller Co.....Baltimore, Md.
Rutherford & Uptegraff.....Pittsburgh, Pa.

Sangamo Electric Co.....Springfield, Ill.
The Sharples Specialty Co.....Philadelphia, Pa.
Shepard Electric Crane & Hoist Co...Montour Falls, N. Y.
Signal Engineering & Mfg. Co.....New York, N. Y.
SKF Industries, Inc.....New York, N. Y.
Square D Co.....Detroit, Mich.
Standard Underground Cable Co.....Pittsburgh, Pa.
Stroh Steel-Hardening Process Co.....Pittsburgh, Pa.
The Superheater Co.....New York, N. Y.
Wm. Swindell & Bro.....Pittsburgh, Pa.

Taplet Mfg. Co.....Philadelphia, Pa.
Thermoid Rubber Co.....Trenton, N. J.
Thomas Flexible Coupling Co.....Warren, Pa.
Thompson Electric Co.....Cleveland, O.
Tool Steel Gear & Pinion Co.....Cincinnati, O.
Trumbull Electric Mfg. Co.....Plainville, Conn.

Union Electric Mfg. Co.....Milwaukee, Wis.
Union Metal Mfg. Co.....Canton, O.
U. S. Graphite Co.....Saginaw, Mich.

Van Dorn & Dutton Co.....Cleveland, O.
V. V. Fittings Co.....Philadelphia, Pa.
Vulcan Soot Cleaner Co.....Du Bois, Pa.

Wagner Electric Corp.....St. Louis, Mo.
Western Electric Co., Inc.....New York, N. Y.
Westinghouse E. & M. Co.....E. Pittsburgh, Pa.
Westinghouse Lamp Co.....Bloomfield, N. J.
Weston Electrical Instrument Co.....Newark, N. J.
West Penn Power Co.....Pittsburgh, Pa.
Edwin L. Wiegand Co.....Pittsburgh, Pa.

York Insulated Wire Co.....New York, N. Y.

Initial Development on Baker River to Be 40,000 Hp.

BY THE expenditure of about $8,000,000 in the building of a 40,000-hp. hydroelectric power plant on Baker River in Skagit County, with transmission lines and necessary substations, the Puget Sound Power & Light Co. within the next 14 mo. will increase its present power output by about 30 per cent and place itself in a position to serve more efficiently all of the Western Washington territory lying north of Everett.

Present plans call for the installation of two 20,000-hp. water wheels, of a design not yet determined, connected

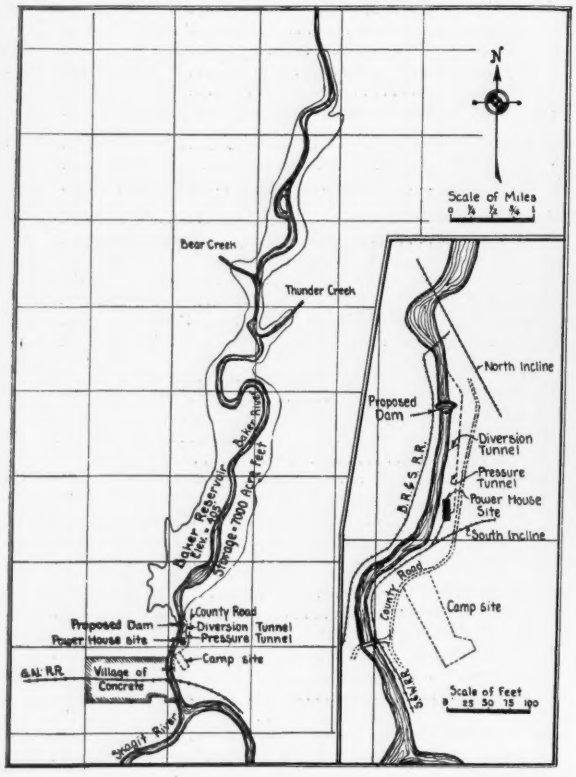


FIG. 1. SITE OF DEVELOPMENT IS IN SKAGIT COUNTY ABOUT A MILE ABOVE CONFLUENCE WITH SKAGIT RIVER

to 18,000-kv.a., 6600-v., 3-phase, 60-cycle generators. The power house will, however, be laid out for future development of the project up to 80,000 hp. The initial expenditures will include a 13,500-kv.a. substation at Sedro Woolley, a 27,000-kv.a. substation at Everett, a 110,000-v. transmission line between Baker River and Everett and a 60,000-v. line between Sedro Woolley and Bellingham. These transmission lines and the power station are under construction at this time and the substations will be built during the summer of 1925. The entire work will be completed in the fall of 1925.

The Baker River rises among the glaciers on the south slopes of Mt. Baker and Mt. Shuksan in Whatcom County, Washington. Near the foot of these peaks a glacial moraine backs up the river to form the beautiful Baker Lake, the elevation of which is 664 ft. above sea level. From the lake the stream flows down mountain gorges and through a long flat valley a distance of some fifteen miles to its confluence with the Skagit River near the town of Concrete, Washington. Just before reaching the Skagit River the Baker flows through a deep gorge, across which the Baker River Dam will be built.

Just before entering the gorge the Baker River flows some 7 mi. through a long flat valley. This valley will form the reservoir which will store up the flood waters of Baker River to an elevation of 405 ft. above sea level. Here will be stored a sufficient quantity of water to cover 70,000 acres one foot deep, which is sufficient to supply the power plant during the dry autumn months. The surface area of this artificial lake will be 1780 acres. The Baker River, being a glacial stream, has a fairly large flow during the summer months, due to the melting glaciers, but decreases during the cool fall weather before the rains set in. At that time the Reservoir will be used to augment the normal stream flow to supply the water wheels.

Near the upper end of the gorge the dam will be built and will be of semi-gravity-arch type and constructed of

FIG. 2. LOOKING DOWN CANYON FROM ADIT B, SHOWING SOUTH PORTAL OF DIVERSION TUNNEL AND POWER HOUSE SITE

concrete. The dam will be 245 ft. high and 180 ft. thick at the base, and will contain about 120,000 cu. yd. of masonry.

Before the dam can be built it will be necessary to dry up that portion of the stream bed to be occupied by the dam, by diverting the river. A tunnel of 336 sq. ft. cross section was therefore bored through the solid limestone rock on the east bank of the river, which will carry the river at normal flow. Cofferdams will then be built above and below the dam site and the stream bed so walled off will then be unwatered, preparatory to construction of the main dam.

The main pressure tunnel is to be 24 ft. in diameter and has been partly bored to form a portion of the diversion tunnel. The completed pressure tunnel will be approximately 1300 ft. long and lined with concrete, and will carry the water from the Reservoir to the penstocks. A surge tank will be provided near the lower end of the tunnel. Gates and rack bars will be provided at the upper end of the pressure tunnel to control the water input. Short steel pipes or penstocks will connect the pressure tunnel with the power house and will carry the water to the turbines.

Power developed will be carried to the Puget Sound Cities by a 110,000-v. transmission line connecting with the company's existing system. The Baker River development is the twelfth hydroelectric generating station of the Puget Sound Power & Light Co. which through ownership or control does the greater part of the commercial electric lighting and power business in western Washington, including the cities of Seattle, Tacoma, Bellingham, Everett, Olympia, Chehalis and Wenatchee.

There are at present 900 men employed on the Baker River development at Concrete Washington, and 300 men employed on the transmission lines. The work is being handled by W. D. Shannon, general superintendent, Puget Sound District, under the direction of S. L. Shuffleton as western manager for Stone & Webster.

Use of Metal Spraying Is Extended

BACK IN 1914 a method of coating surfaces by spraying with molten metal was described in Power Plant Engineering. Since the equipment used with this process

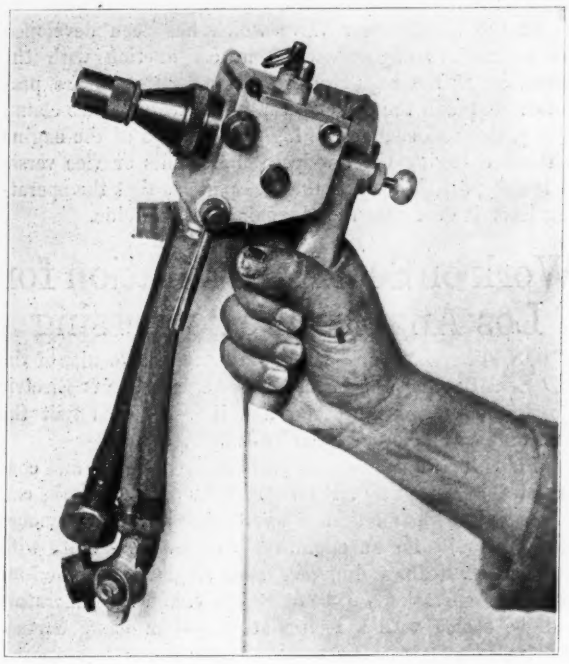


FIG. 1. WIRE FEED TYPE OF METAL SPRAYING GUN

has been considerably improved and the field of applications extended to cover work in the power plant field.

1. Metal in wire form of the standard commercial gages and with which coatings of copper, brass, bronze, German silver, aluminum, zinc, lead, tin, iron, nickel and monel metal may be sprayed.

2. Metal in the form of dust with which zinc, aluminum, tin and lead are usually handled.

3. "Mass coating" a combination of either one of the above, with a specially constructed rumbling barrel and with which articles weighing from a fraction of an ounce up to 10 lb. each may be treated in lots of approximately 100 lb. at a time. The development of this type extends the field of use for the process so that it is now favorably comparable as to cost of operation with any of the older methods of metal coating this class of materials.

The metal depositing gun for use with wire, weighing 3½ lb., is connected to standard acetylene and oxygen cylinders and to a supply of compressed air, consuming, while in use, approximately 15 cu. ft. each of the gases per hour and 50 cu. ft. per minute at 50 lb. pressure of the air. Metal in the form of standard gage wire is automatically pulled from a reel into the rear of the gear case and fed uniformly and continuously at a rate of from 12 to 24 ft. per min. to the muzzle of the short barrel, where

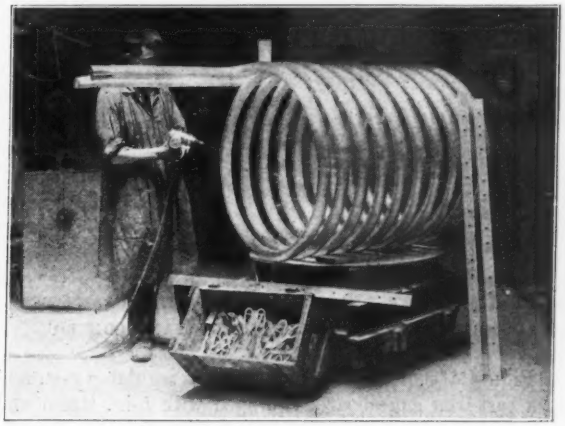


FIG. 2. SPRAYING A REFRIGERATING COIL WITH TIN

it enters into a continuous reducing flame zone developed from the gases and air and is there melted and blown at a velocity of about 3000 ft. a second (equal to the speed of a rifle bullet) in a fine spray onto the surface being coated.

Within the gear case, the mechanism consists of an air driven turbine operating a wire feeding and straightening device for leading the metal into the barrel. The wire remains cold and unaltered until it emerges from the muzzle at a point about $\frac{3}{32}$ in. from which it is melted and undergoes transformation into spray.

The muzzle is aimed at the surface to be coated and held 3 to 4 in. therefrom and in this short distance takes place the change of the wire from a solid to a molten state, thence to the spray and instantly back to the solid, practically cold coating. The temperature of the surface being coated is raised but slightly.

An interesting application is the coating with aluminum of parts subjected to high temperatures. This retards oxidization and scaling and in grate bars and similar pieces prevents clinkers from adhering.

Such treatment has been applied to distributors in automatic stokers, condenser tubes, pyrometer couple tubes, boiler tube cleaning equipment, gas and electric oven and muffler parts, rheostat and electric heater resistances, exhaust manifolds, valves, pistons and explosion chambers of internal combustion engines and parts exposed to contact with molten glass.

Correction Note

IN CONNECTION with the description of the Thermix air heater on page 980, September 15 issue, a typographical error makes it appear that the resistance to gas flow through the heater is 2 to 4 in. of water. This should be 0.2 to 0.4 in.

New Regulators Added to Defender Line

SEVERAL new devices have been added to the line of combustion control equipment built by the Defender Automatic Regulator Co., of St. Louis. These new developments include a master damper regulator, a furnace pressure regulator and a chronometer valve for controlling the speed of stoker, fan or blower engines.

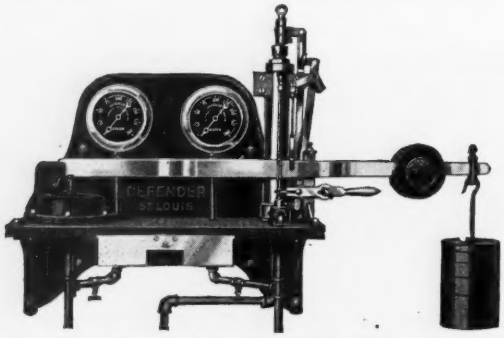


FIG. 1. MASTER DAMPER REGULATOR HAS GRADUATED COMPENSATOR AND INDEPENDENT HAND CONTROL

Figure 1 shows the master damper regulator mounted on a cast-iron gage board, equipped with 5-in. steam and water pressure gages. The steam line from the main header is connected to the steam diaphragm by means of the pipe connection at the left. At the right is the water supply connection to the water valve while the center connection is for the waste water pipe.

In this regulator the compensating mechanism operates in connection with the weight beam and is independent of the water valve. It is possible to disconnect the compensator and the regulator operates as a positive type.

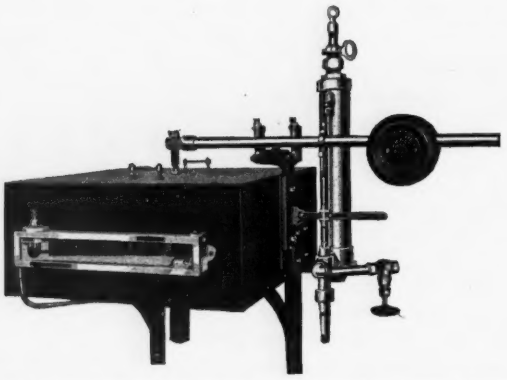


FIG. 2. FURNACE DRAFT REGULATOR WITH WEIGHT ADJUSTMENT AND AUXILIARY HAND CONTROL

The compensator is adjustable to work on any steam pressure variation from 1 to 10 lb. and still to allow a full 10-in. stroke of the piston in the cylinder. This compensator is adjusted after the regulator is in use in accordance with the steam demand or load variation on the boilers. For light load variation, from 1 to 3 lb. compensation is recommended, 3 to 5 lb. for higher load variations and 5 to 8 lb. for extreme load variations.

Below the weight beam and at the right of the machine is a hand lever for controlling the pilot valve independently of the steam pressure. The lever is slid to the left through a slotted bearing and forms a clevice grip on two collars on the stem of the pilot valve and then by lowering or raising the handle and locking it with a thumb screw, the position of the damper can be held at any desired point. This hand operation is used for banked fires or for opening the dampers and speeding up the stoker and fan engines in advance of a load or for slowing down in advance of a drop in load.

Figure 2 shows the furnace draft regulator of the inverted hollow bell, or gasometer, type for controlling the draft over the fire on forced-draft stoker-fired boilers. It may also be used to control a damper between the blower and stoker where one blower is furnished to operate several stokers. It may also be used to open or close the boiler damper where this is desired.

On the right-hand side of the regulator is shown the water cylinder but it can be removed and mounted on the left-hand side as holes are drilled and tapped for such a purpose. Below the main balance beam a small lever is provided for operating the regulator independently of the draft conditions. Throttling a needle point valve on the inlet water controls the travel or speed of the piston in closing the dampers or valves.

In the chronometer valve which has been developed for controlling engine speeds, in conjunction with the operation of the regulator, several adjustments are provided. Through the use of a center clevice and face clamp it is possible to change the high-speed steps of the engine without changing the low-speed increments or vice versa. It is also possible to shift the face plate so that the operating lever is on either the right or left-hand side.

Work on Seal Beach Station for Los Angeles Is Progressing

CONSTRUCTION in Orange County, California, of the Seal Beach plant for the Los Angeles Gas & Electric Co. is making good progress and it is expected that the first unit will be in operation by June 1, 1925.

Plans for the station, which is being designed and constructed by Dwight P. Robinson, Inc., of New York, call for an initial installation of two 30,000-kw. Westinghouse turbines, built for an operating pressure of 350 lb. with 700 deg. F. steam and arranged for stage bleeding at four points. Generation will be at 13,200 v. and the generators will be cooled with a recirculating system using surface coolers.

As this is to be an oil fired plant no particularly difficult fuel handling problems are involved. There will be six boilers of the Babcock and Wilcox cross drum type with 24,450 sq. ft. of heating surface and three passes for the flue gas. Gage pressure will be 375 lb. with 256 deg. superheat. Air preheaters will be used and economizers have been eliminated.

Since this is an oil fired plant, the details of the furnace ratios are of particular interest. The furnace volume is 3.80 cu. ft. per rated boiler horsepower or 1.26 cu. ft. per developed boiler hp. at 300 per cent rating. According to calculations the rate of burning fuel will be 1.40 lb. per hr. per cu. ft. of furnace volume, with an oil of 18,500 B.t.u. per lb. Hollow wall furnace construction will be used. There will be one 375-ft., 23-ft. in diameter steel stack for every six boilers.

Auxiliaries will be electric driven throughout and alternating current for the purpose will be supplied by a 1250-kw. house generator direct connected to the main unit. Condensers will be two pass type with 1.5 sq. ft. of tube surface per kw. of turbine rating.

Work on the plant was begun on April 1. Since that time the foundations have been completed and work on the buildings is now under way. The main building will be 200 by 300 ft. No attempt has been made to estimate the ultimate rating of the plant as this will depend entirely on the future growth of the load.

Flight Conveyor Is Portable

AFTER carrying on some extensive experimental work, the Gifford-Wood Co. of Hudson, N. Y., recently brought out a portable flight conveyor for use in un-

LOADING A TRUCK WITH COAL WITH PORTABLE FLIGHT CONVEYOR

loading hopper bottom cars, loading from ground storage to trucks and other such service.

In this conveyor the steel flights, of channel formation are riveted to endless strands of pintle chain. The frame is constructed of two side channels with a flat plate bolted to the bottom flanges thus forming the trough. As this plate is subjected to wear it is arranged so that it is readily removable for replacement. The supporting frame is of pipe and angle construction.

An electric motor, rated at 3 hp. is used for operating the conveyor or, if desired, a 5 hp. gasoline engine may be used. A geared lifting mechanism is provided for regulating the height of the discharge. The capacity is 1 T. per min. when fed continuously.

Power Show Broadening Its Scope

DUE TO the great interest that has been shown in past Power Shows by the executives and engineers that visited them, the exhibitors have been stimulated to great efforts to develop interesting and instructive showings of the progress during the past year in the arts and sciences of producing, distributing and using power. The Third National Exposition of Power and Mechanical Engineering will be held in the Grand Central Palace, New York, from December 1 to 6, 1924. The preceding shows have thoroughly covered the field of power production with the exception of hydraulic machinery but in the coming event there will be an excellent representation of the manufacturers of large turbines and hydraulic power plant equipment.

One of the important features of the Power Show is its educational value which will be broadened by a series of lecture courses in conjunction with the show. Competent lecturers will treat the critical problems of power development and those who attend will then have the opportunity to go out on the floor of the exhibit and observe how the problems are solved by the different manufacturers represented. The courses will be open to students at engineering schools, the faculties of which are co-operating with the management of the Exposition. The lectures will be arranged so that they will not conflict with the the sessions of The American Society of Mechanical Engineers and the American Society of Refrigerating Engineers whose Annual Meetings will be held the week of the Power Show.

News Notes

B. N. BROIDO, who has been doing special consulting work for The Superheater Co., of New York and Chicago, has recently been appointed chief engineer of the Industrial Department of the company.

W. J. BROWN, who has for the last 5 yr. been chief engineer for the Oklahoma Gas and Electric Co. at Oklahoma City, has accepted the position of chief engineer of the company's new plant at Harrah, Okla. Mr. Brown has been with the company for 18 yr. E. A. Light, who was Mr. Brown's assistant is now chief engineer at Oklahoma City.

AT A RECENT meeting of the board of directors of the Howard Iron Works, Chicago and Granger Sts., Buffalo, Charles E. Clark was elected president and general manager and C. F. Kneiser, vice-president. Henry J. Turner, general manager for the past year and a half, has resigned as has also O. E. Frank, who was in charge of sales in the heater and expansion joint department. This department will be under the supervision of the company's chief engineer, E. A. Hahl. The same officers also head the Alberger Heater Co., an affiliated company.

WILLAPA POWER CO., SOUTH BEND, WASH., has recently completed a 200-hp. semi-Diesel plant, which will be held as a stand-by at low water stage, when the water power plant will not supply this load. It is possible that speed records were broken in the erection of this unit. No ground had been broken at the building site when on July 11, 1924, the order for engine and generator was placed with Fairbanks Morse & Co. at Beloit, Wis. The

generator was shipped from Fort Wayne, Ind., to Beloit, while the engine was assembled and tested out. Shipment arrived in South Bend, Wash., Aug. 9 and 18 days later, Aug. 27, the plant was operating. Switchboard and transformers are General Electric and Weston instruments are used. The plant was designed and built by O. B. Edwards, chief engineer of the Willapa Power Co.

Pacific Power & Light Co. will soon complete the work of installing a new 5000 kw. General Electric steam turbine at the Young's Bay Plant, Astoria, Ore. Superintendent of Construction J. E. Shinn is now at the plant expediting the work. This installation will bring the capacity of the Young's Bay Plant to 8500 kw. which the present boiler equipment will take care of. R. A. Horton is chief engineer of this unit.

Washington Veneer Co., Olympia, Wash., recently broke ground for their new veneer plant. It is believed that upon completion of present plans the company will have the best modern plant of its kind on the Pacific Coast. The boiler room will contain two B. & W. 300-hp. boilers, Worthington horizontal pumps, automatic feed water regulators, elevator for wood refuse (sawdust) burning. Chas. C. Moore Engineering Co., San Francisco, will do the installation work. When finished, the operation of the plant will be under direction of O. Jacobson, electrical engineer.

Sometime next year the Duquesne Light Co. of Pittsburgh, expects to begin construction work on a new power station to be located at Shippingport on the Ohio River in Beaver County. The initial development is expected to cost about $10,000,000 although the purchase of 2000 acres of coal land near the site assures an adequate fuel supply for the ultimate development of 300,000 kw.

At the present time the Duquesne Light Co. service is supplied by the Colfax and Brunot Island plants which feed into a 60,000-v. net work which encircles the city. The new station will be similar in design to the Colfax station.

Books and Catalogs

Defender Automatic Combustion Control for Fuel Saving in the Boiler Room is a series of loose leaf bulletins, which have been combined as Catalog No. 19 by the Defender Automatic Regulator Co., of St. Louis. The various bulletins take up in some detail, the line of automatic damper regulators, chronometer valves, regulating valves, pressure governors and the various other devices which are built by this organization.

The Hell Gate Tests is not an abstract from Dante's Inferno but is an interesting booklet published by the American Engineering Co. of Philadelphia, Pa., giving interesting results of operation of the plant in the Hell Gate Station of New York City. The tests are particularly on the boiler plant which is fired by Taylor stokers. Copies of the booklet may be had by writing to the American Engineering Co., Aramingo and Cumberland Streets, Philadelphia, Pa.

Busch-Sulzer Diesel Engines are described in a 96-page catalogue published by the Busch-Sulzer Bros.-Diesel Engine Co. of St. Louis, Mo. The principles of Diesel engine operation are covered and considerable information is given as to the efficiencies of various types of power plants. In this comparison, curves are used to show the fuel consumption in B.t.u. per b.hp.-hr. for different types of steam engines and turbines as compared with that required for the Diesel engine. A comparison is also made as to floor space required and the subject of fixed charges is also discussed. It is pointed out that the straight line method of figuring fixed charges is apt to be misleading. A table shows the sinking fund expressed as a percentage of first cost for various rates of interest and year's life of equipment. In addition to this general information, the construction features of the Busch-Sulzer engines are covered in considerable detail together with illustrations of numerous installations.

Group insurance for employes, what it is and how it works, is explained in a booklet sent out by the Travelers Insurance Co. of Hartford, Conn. It explains one method of showing appreciation of loyal service of those who help make an organization a success.

Refractory Mortar is a booklet on the application of DURA-STIX for bonding and extending the life of fire brick in boiler and metallurgical furnaces, which has been published by the Keystone Refractories Co., 120 Liberty St., New York.

In issue No. 4 of Ice & Frost, a publication issued periodically by the Frick Co. of Waynesboro, Pa., some of the uses of mechanical refrigeration are described. The second part of the bulletin covers vertical enclosed compressor and refrigerating equipment.

The History of District Steam Heating is a digest of four talks broadcast by radio from Lockport, N. Y., by G. H. West, Secretary of the American District Steam Co., North Tonawanda, N. Y. The digest of these talks is particularly interesting from an historical standpoint, as they are illustrated with drawings which show the early practice in district steam heating, together with the more modern developments along this line.

Electro-Sherardizing is the subject of Bulletin No. 40, published by the Steere Engineering Co., of Detroit, Mich. This process of sherardizing, which consists of the condensation of zinc vapor in and on the surface of iron or steel, is explained and its particular advantages are discussed.

Directory of the members of the British Association of Engineers and their manufactures for 1924, is just received from the secretary of the Association. The object of the directory is to furnish to all interested the names, addresses, telegraphic addresses, codes and full particulars of their products of British manufacturing engineers. Objects of the Association are to serve as a clearing house of information for those wishing information about manufactures, to investigate overseas markets for the members, to promote co-operative action, to assist research, invention and education and, in general, to promote the interests of the members. In the directory are given the names of the members and announcements of their products. A copy will be sent to any interested purchaser of engineering products or inquiries as to firms or engineering manufacturers, in any language, will be answered on addressing a request to the secretary, Alfred Parker, 32 Victoria St., Westminster, London, S. W. 1, England.